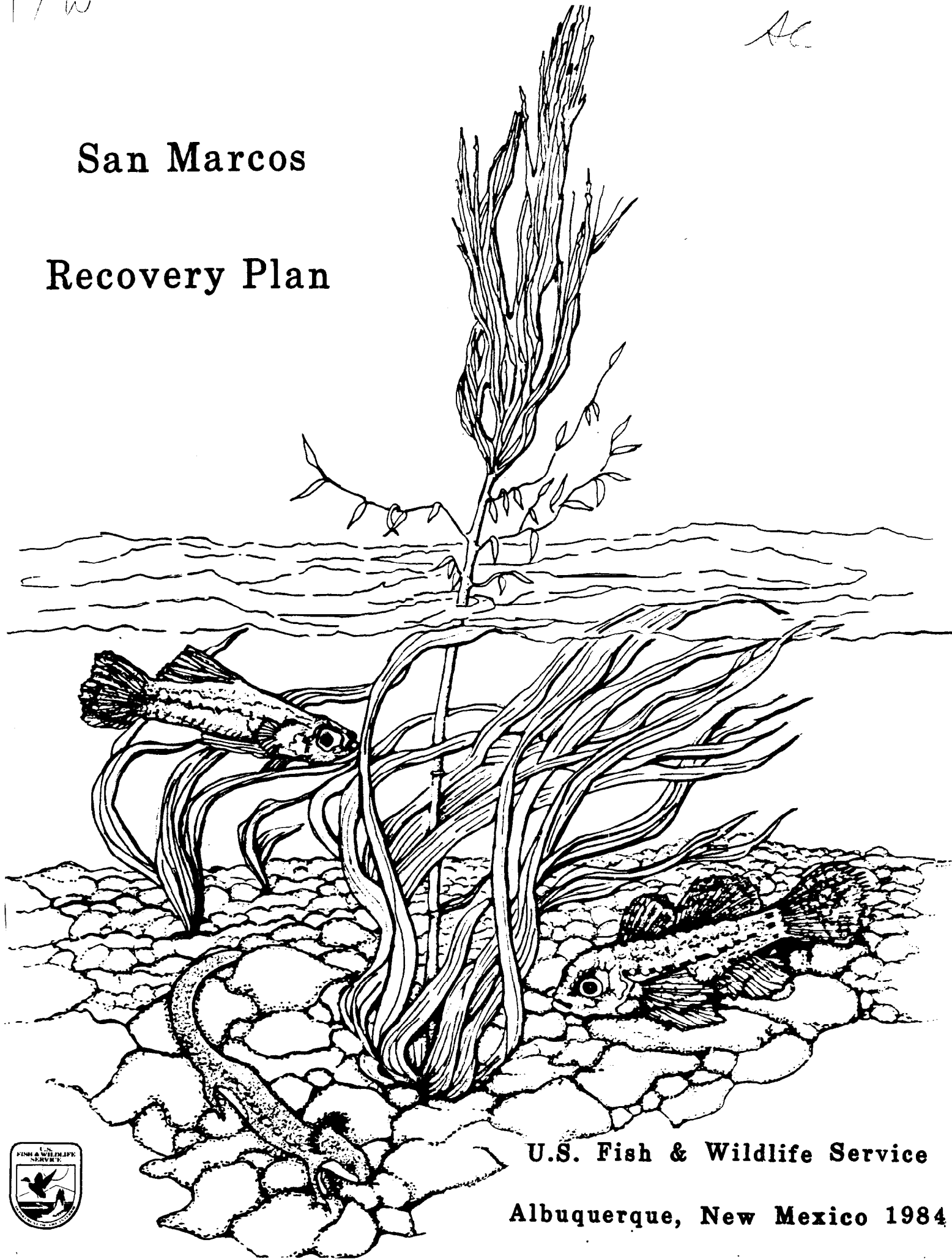


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# San Marcos

## Recovery Plan



U.S. Fish & Wildlife Service

Albuquerque, New Mexico 1984



The San **Marcos** Recovery Plan

FOR

San **Marcos** River Endangered and Threatened Species

San **Marcos** Gambusia (Gambusia **georgei**) Hubbs and Peden  
Fountain Darter (Etheostoma fonticola) (Jordan and Gilbert)  
San **Marcos** Salamander (Eurycea **nana**) Bishop  
Texas **Wildrice** (Zizania **texana**) Hitchcock

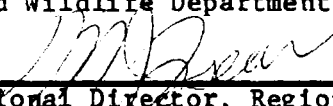
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Regional Director, Region 2  
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Date:  4/8/85

## SUMMARY

### 1. GOAL:

Secure the survival and eventual recovery of the San **Marcos** gambusia, fountain darter, San Marcos salamander, and Texas **wildrice** through protection of their natural ecosystem, the San **Marcos** River.

### 2. THREATS:

The San Marcos River ecosystem and the biota comprising the system are endangered by a number of threats. The most serious is cessation of flow of thermally constant, clear, clean water from the San **Marcos** Springs due to overdrafting of groundwater from the Edwards Aquifer. Other threats include habitat modification and/or loss from anthropogenic actions in the river, along the river bank, and on the watershed. Exotic species are becoming increasingly common. The effects of the exotics **combined** with habitat modification may synergistically extirpate species, such as the San Marcos **gambusia**, relatively soon.

### 3. RECOVERY CRITERIA:

The species can be downlisted to threatened when it is assured that flow in the San **Marcos** River will continue, **withinits** natural cycle of variation. Delisting is not addressed in this phase of recovery.

### 4. ACTION NEEDED:

Major steps to **meeting** the recovery criteria include: monitor populations and habitats, identify requirements, manage the river for the benefit of the species (establish guidelines, reduce pollution, **augment** recharge, establish pumping controls), and establish recreational guidelines. Short-term "emergency" actions include bringing the species into protected refugia and preparations to supplement flows in the river via pumping. Long-term actions include working with water managing agencies to assure flows in the San **Marcos** River.

## DISCLAIMER

The San Marcos Recovery Plan was developed by the San Marcos Recovery Team (SMRT), an independent group of biologists sponsored by the Albuquerque Regional Director of the U.S. Fish and Wildlife Service.

The recovery plan is based upon the belief that local, State, and Federal agencies, private organizations, and interested individuals should make every attempt to preserve the upper San **Marcos** River ecosystem which contains among other life forms, the San Marcos gambusia, the Eountain darter, the San **Marcos** salamander, and the Texas wildrice. The SMRT further believes that these groups also should endeavor to preserve the habitat of these species and to restore their populations, as much as possible, to their historic status. The objective of the plan is to make these beliefs reality.

The San **Marcos** Recovery Team used the best information available for its determinations and has used its collective knowledge and experience in producing this draft recovery plan. Hopefully, the completed plan will be utilized by all agencies, institutions, and individuals concerned with the San Marcos gambusia, the San **Marcos** salamander, the Texas wildrice, and the fountain darter and the San **Marcos** River ecosystem in order to better coordinate conservation activities. As the completed plan is implemented, and as new information becomes available, revisions will be necessary. Implementation is the task of the managing agencies, especially the U.S. Fish and Wildlife Service and the Texas Parks and Wildlife Department. All **management** efforts will be accomplished in cooperation with appropriate agencies.

This is the completed San **Marcos** Recovery Plan. It has been approved by the U.S. Fish and Wildlife Service. It does not necessarily represent official positions or approvals of cooperating agencies and it does not necessarily represent the views of all recovery team members who played the key role in preparing this plan. This plan is subject to modification as dictated by new findings and changes in species status and completion of tasks described in the plan. Goals and objectives will be attained and funds expended contingent upon appropriations, priorities, and other budgetary **constraints**.

Literature citations should read as follows:

U.S. Fish and Wildlife Service. 1984. San **Marcos** River Recovery Plan.  
U.S. Fish and Wildlife Service, Albuquerque, New Mexico. pp. v + 109.

Additional copies may be obtained from: Albuquerque Regional Office of  
Endangered Species, P.O. Box 1306, Albuquerque, New Mexico 87103.

Fish and Wildlife Reference Service, 6011 Executive Blvd., Rockville,  
Maryland 20852 Phone: (301) 770-3000; Toll Free 1-800-582-3421

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## PART I

### INTRODUCTION

The San **Marcos** River arises in a series of spring openings along the Balcones Fault Zone in the City of San Marcos, Hays County, Texas. The second largest spring system in Texas, the springs at San **Marcos** historically have exhibited the greatest flow dependability and environmental stability of any spring system in the southwestern United States. Records indicate that the San Marcos Springs have never ceased flowing, although the flow has varied and is tied to fluctuations in their source, the Edwards Aquifer underlying the Balcones Fault Zone. Partly because of the constancy of its waters, the San **Marcos** Springs ecosystem, including its springrun, the San **Marcos** River, has a greater known diversity of aquatic organisms than any other ecosystem in the southwestern United States.

The biological uniqueness of this system has been known for many years. Many of the species found in the San **Marcos** River ecosystem are found nowhere else and are restricted to the first few kilometers or less of the San Marcos springrun. Other forms are nearly as range restricted and are limited to the largest spring system in Texas--the springs issuing into the Comal River in nearby New Braunfels, **Comal** County, Texas--in addition to the San **Marcos** River ecosystem.

Due to a variety of factors, including increased use of the aquifer waters for human activities, increased urbanization in the San Marcos region resulting in increases in flood intensity, pollution, recreational use and alterations of the river, the San **Marcos** River ecosystem is in

danger of losing its unique flora and fauna. Presently, four San Marcos River species are recognized by the U.S. Fish and Wildlife Service as organisms threatened with or in danger of extinction; the San Marcos gambusia (Gambusia georgei) Hubbs and Peden, the fountain darter (Etheostoma fonticola) Jordan and Gilbert, the San Marcos salamander (Eurycea nana) Bishop, and the Texas **wildrice** (Zizania texana) Hitchcock.

Recovery measures to restore these species to their former levels of abundance are presented in this recovery plan. This San Marcos Recovery Plan is the first recovery plan to address the recovery of multiple species through an ecosystem approach. The importance of conservation of the entire San Marcos ecosystem as the only approach for recovery of these four species was recognized early in the development of this plan. Any recovery plan for the San Marcos endangered and threatened species that fails to address the continued functioning of the ecosystem, would fail to achieve the recovery and downlisting of these species. The objective of this recovery plan is to document the problems each of these listed species are facing and to present a set of actions which when accomplished should remove the threats to the species and result in their recovery and delisting.

## **Physiography, Hydrology and History of the San Marcos River**

### Physiography

The **Balcones** Fault Zone is the principal geological feature characterizing the San Marcos area. This fault zone separates the Edwards Plateau vegetation region from the Blackland Prairies and South Texas Plains regions (Fig. 1). These regions correspond to the Balconian, Texan and Tamaulipan Biotic Provinces respectively, of Blair (1950).

The headwaters of the San Marcos River issue from several large fissures and numerous smaller solution openings along the San Marcos Springs fault (Puente 1976). Early Spanish explorers estimated that a series of 200 springs **made up** the main spring area (Brune 1981). The springfed San Marcos River flows primarily southeastward for approximately 110 km before joining the Guadalupe River in the vicinity of Gonzales, Gonzales County, Texas. The upper San Marcos River is a rapidly flowing, unusually clear springrun some 5-15 m wide and up to approximately 4 m deep. For the first few kilometers, to near the **Blanco** River confluence,, the river flows mostly over a firm gravel bottom with many shallow riffles alternating with deep pools. The section between the **Blanco** River confluence and the Guadalupe River has fewer attributes of a springrun.' Upstream from the junction of the **Blanco** River with the San Marcos River, approximately 6.4 km below the main springs in San Marcos, three creeks, various storm sewers, and one wastewater treatment plant discharge into the river. Sink Creek, largest of the three creeks, discharges large quantities of storm runoff from the north into Spring Lake. Spring lake dam backs

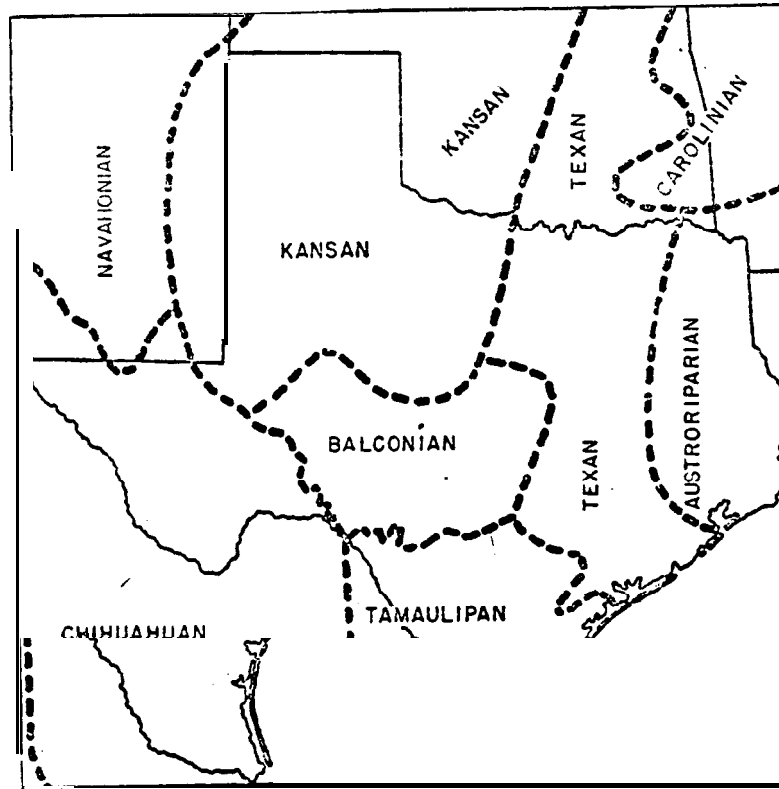


FIG 1

Approximate boundaries of biotic provinces in Texas, Oklahoma and parts of adjacent states.

water approximately 1.6 km up Sink Creek. The other two creeks, Willow Springs and Purgatory Creeks, are normally dry except during periods of high rainfall.

### Hydrology

The San Antonio Region of the Balcones Fault Zone extends as a series of faults and fracture lines from the vicinity of Brackettville (Kinney County) east to San Antonio (Bexar County) and then northeast to near Kyle (Hays County). A major aquifer (Edwards Balcones Fault Zone Aquifer) underlies this fault zone and is the source of water for San Marcos Springs (Fig. 2). Runoff from the southern and eastern portions of the Edwards Plateau recharge this aquifer through the porous Cretaceous-aged limestones found in this region. Water from this recharge flows along the fault zone from west to east and then northeast. Major springs located along this fault system include the two largest springs in Texas, Comal Springs in New Braunfels (Comal County) and San Marcos Springs in San Marcos (Hays County).

The flow of San Marcos Springs has been monitored intermittently since 1894 (Puente 1976). Average annual spring flow is  $4.46 \text{ m}^3/\text{s}$  (161.0 cfs) (Guyton and Associates 1979). During drought years much lower flows occurred, especially during the mid-1950s when Comal Springs did not flow for part of one year. The lowest recorded monthly flow from San Marcos Springs was  $1.53 \text{ m}^3/\text{s}$  (54 cfs) during 1956 (Guyton and Associates 1979). The lowest measured daily flow rate occurred on 15 and 16 August 1956 when the San Marcos River flowed at only  $1.29 \text{ m}^3/\text{s}$



(45.55 cfs). Maximum daily spring flows can be greater than  $8.33 \text{ m}^3/\text{s}$  (294.13 cfs), especially following periods of high local rainfall and runoff (Puente 1976).

The thermally constant water from the San Marcos Springs has long been noted (Brown 1953) and generally varies annually by less than  $1-2^\circ\text{C}$  in the headwaters. At the lower end of the springrun habitat only a slightly greater range of variation in temperature (from  $25.5^\circ\text{C}$  in August to  $20.4^\circ\text{C}$  in February) has been recorded (USDI 1967-1971, Beaty 1972). Waters tend to be alkaline or neutral due to the limestone aquifer. The ~~PH~~ range of the San Marcos Springs is 6.9-7.8 (Texas Water Development Board 1968). The stability of this stream, both in terms of flow dependability and thermal characteristics, probably provided the appropriate ecological conditions necessary to allow the unusually high degree of endemism of the San Marcos biota.

In addition ~~to their~~ occurrence in the San Marcos River system, two listed species under consideration (Etheostoma fonticola and Eurycea nana) also occur in the Comal River. A detailed description of ~~the~~ hydrology of Comal Springs appears in the species account of Etheostoma fonticola.

#### History

A brief historical **overview** of the earliest inhabitants and visitors to the San Marcos Springs is provided by Brune (1975, 1981). Originally

called "Canocanayesatetio" (meaning "warm water") by the Tonkawas living near ~~the~~ springs, the San Marcos area was colonized by this tribe and later by the **Comanches**. The first Europeans to see the springs were probably members of ~~the~~ Espinosa-Olivares-Aguirre expedition in 1709. In 1755 the San Xavier missions (Milam County) were moved to San Marcos but soon were moved further south to the Comal Springs area because of lack of irrigation facilities and a severe drought in 1756. The springs were an important stop on El **Camino** Real from Mexico to Nacogdoches. In 1807, Mexico established the settlement of San Narcos de Neve approximately 6 km downstream from the springhead; however, floods and Indian attacks caused its abandonment in 1812. Following these events, the City of San Marcos developed in the more protected area surrounding the headsprings.

In 1835 settlers from the United States with Mexican land grants began to move into the area and water from the river was used for power plants and cotton gins as well as corn, saw, and grist mills. An ice factory later became another user of the water from the San Marcos Springs. From 1867 to 1895 the springs were a stop on the Chisholm Cattle Trail. In the late **1890s**, an early Federal fish hatchery was established near the springs based on prior suitability studies (Jordan and Gilbert 1886). Spring Lake (altitude 189 **m**) was created over fifty years ago by the damming of the San Marcos River not far downstream from the headsprings. The clarity of its water has made Spring Lake the site of a major tourist attraction, **Aquarena** Springs, Inc., a private amusement park featuring glass-bottomed boat rides and a submarine theater.

The population of the City of San Marcos, Hays County, Texas rose from 741 in 1870 to 23,420 in 1980 (U.S. Bureau of the Census 1982); no other county along the **Balcones** Fault Zone had a greater relative growth than Hays County for the period 1960-1980. Continued rapid population growth of the City of San Marcos and Hays County, including projected increases in enrollment at Southwest Texas State University in the city, is expected.

#### Species Accounts

Four San Marcos River species are presently recognized as either endangered or threatened by the U.S. Department of the Interior:

San Marcos gambusia, Gambusia georgei (FR Vol. 45: 47355-47364; July 14, 1980);  
Fountain darter, Etheostoma fonticola (FR Vol. 35: 16047; October 13, 1970;  
FR 45:47355-47364; July 14, 1980);  
San Marcos salamander, Eurycea nana (FR Vol. 45: 47355-47364; July 14, 1980);  
Texas wildrice, Zizania texana (FR Vol. 43: 17910-17916; April 26, 1978;  
FR Vol. 45:47355-47364; July 14, 1980).

Classifications that various governmental and conservation groups have given to these species appear in Table 1. Note **that** biological conservation groups closely agree on the degree of threat faced by the four San Marcos species.

Table 1

<u>Species</u>	<u>Organization</u>			
	<u>FWS</u>	<u>TPWD</u>	<u>TOES</u>	<u>IUCN</u>
<u>Gambusia georgei</u>	E	E	E	E
<u>Etheostoma fonticola</u>	E	E	E	E
<u>Eurycea nana</u>	T	P*	T	R
<u>Zizania texana</u>	E	E	E	V

FWS = U.S. Fish and Wildlife Service

TPWD = Texas Parks and Wildlife Department

TOES = Texas Organization for Endangered Species

IUCN = International Union for Conservation of Nature and Natural Resources

E = Endangered

R= Rare

T = Threatened

V = Vulnerable (=Threatened)

P = Protected nongame (P\* = P.N.G.)(=Threatened)

San Marcos Gambusia (Gambusia georgei)

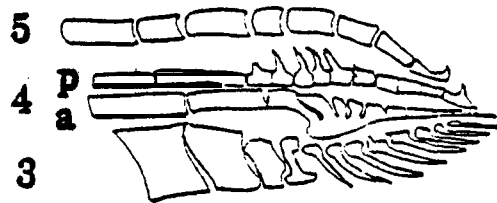
Introduction and Background: The San Marcos gambusia (Gambusia georgei) was first described from the biologically diverse San Marcos River system of central Texas in 1969. Of the three species of Gambusia native to the San Marcos River, G. georgei apparently always has been much less abundant than **either** the largespring gambusia (G. geiseri) or the mosquitofish (G. affinis) (Hubbs and Peden 1969).

The San Marcos gambusia is a member of the Poeciliidae and belongs to a genus having more than 30 species of livebearing freshwater fishes of Central American origin. The genus Gambusia is well defined and mature males may be distinguished from related genera by their thickened upper pectoral fin rays (Rosen and Bailey 1963). Only a limited number of Gambusia are native to the United States and of this subset, G. georgei has the most restricted range. The San Marcos gambusia is plainly marked and is subtly different from the mosquitofish (G. affinis). Scales tend to be strongly crosshatched in contrast to **the** less distinct markings on the scales of G. affinis. In addition, G. georgei tend to have a prominent dark pigment stripe **across** the distal edges of their dorsal fins. A diffuse mid-lateral stripe extending posteriorly from the base of the pectoral fin to the **caudal** peduncle is also often present, especially in dominant individuals. As in G. affinis, a dark subocular bar is visible

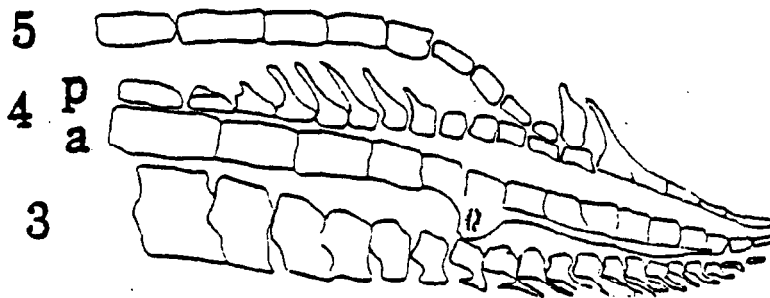
and is elicited easily from frightened fish. Compared to *G. affinis*, *G. georgei* has fewer spots and dusky pigmented regions on the caudal fin. The median fins of wild-caught specimens of San Marcos gambusia tend to be lemon yellow. In a dominant or "high" male, this color can approach a bright yellowish-orange, especially around the gonopodium. A bluish sheen is evident in more darkly pigmented individuals, especially near the anterior dorsolateral surfaces of adult females.

Gonopodial structures of males classically have been employed in dealing with *Gambusia* systematics. *G. georgei* is unique morphologically from other species in several characters, including the presence of more than five segments in ray 4a which are incorporated into the elbow and also by the presence of a compound claw on the end of ray 4p (Hubbs and Peden 1969) (Fig. 3).

Historic and Present Distribution: The San Marcos gambusia is represented in collections taken in 1884 by Jordan and Gilbert during their surveys of Texas stream fishes and in later collections (as a hybrid) taken in 1925 (Hubbs and Peden 1969). Unfortunately, records of exact sampling localities are not available for these earliest collections. Localities were merely listed as "San Marcos Springs." These collections likely were taken at or near the headsprings area. If this is true, then *G. georgei* appears to have significantly altered its distribution over time. Importantly, samples taken prior to 1950 from the San Marcos River downstream from the headsprings are extremely scarce.



(A) Gambusia georgei



(B) Gambusia affinis

Fig. 3. Fin ray elements characteristic of the **gonopodium** (anal fin) of Gambusia georgei (A), and Gambusia affinis (B), the species most likely to be confused with G. georgei (modified from Hubbs and Peden 1969, Hubbs and Springer 1957).

During 1953, a single individual was taken below the low dam at Rio Vista Park; however, since that time, nearly every specimen of G. georgei has been taken in the vicinity of the Interstate Highway 35 bridge crossing downstream to the area surrounding Thompson's Island (Fig. 4). The single exception to this was a male taken with an Ekman dredge approximately 1 km below the outfall of the San Marcos Secondary Sewage Treatment Plant in 1974 (Longley 1975).

Presently, G. georgei apparently is restricted to the approximately 1 km portion of the San Marcos River between Interstate Highway 35 and the USGS gaging station **immediately** downstream from Thompson's Island (Fig. 4). San Marcos gambusia populations are extremely sparse; intensive collections during 1978 and 1979 yielded only 18 G. georgei from 20,199 Gambusia total (0.09%) (Edwards et al. 1980). Recent (1981/82) collections within the range of G. georgei indicate a slight decrease (0.06% of all Gambusia) in relative abundance of this species (Edwards unpubl. data).

Habitat Requirements: The San Marcos gambusia apparently prefers **quiet** waters adjacent to sections of moving water, but seemingly of greatest importance, thermally constant waters. G. georgei is found mostly over muddy substrates but generally not silted habitats, and shade from overhanging vegetation or **bridge** structures is a factor common to all sites along the upper San Marcos River where apparently suitable habitats for

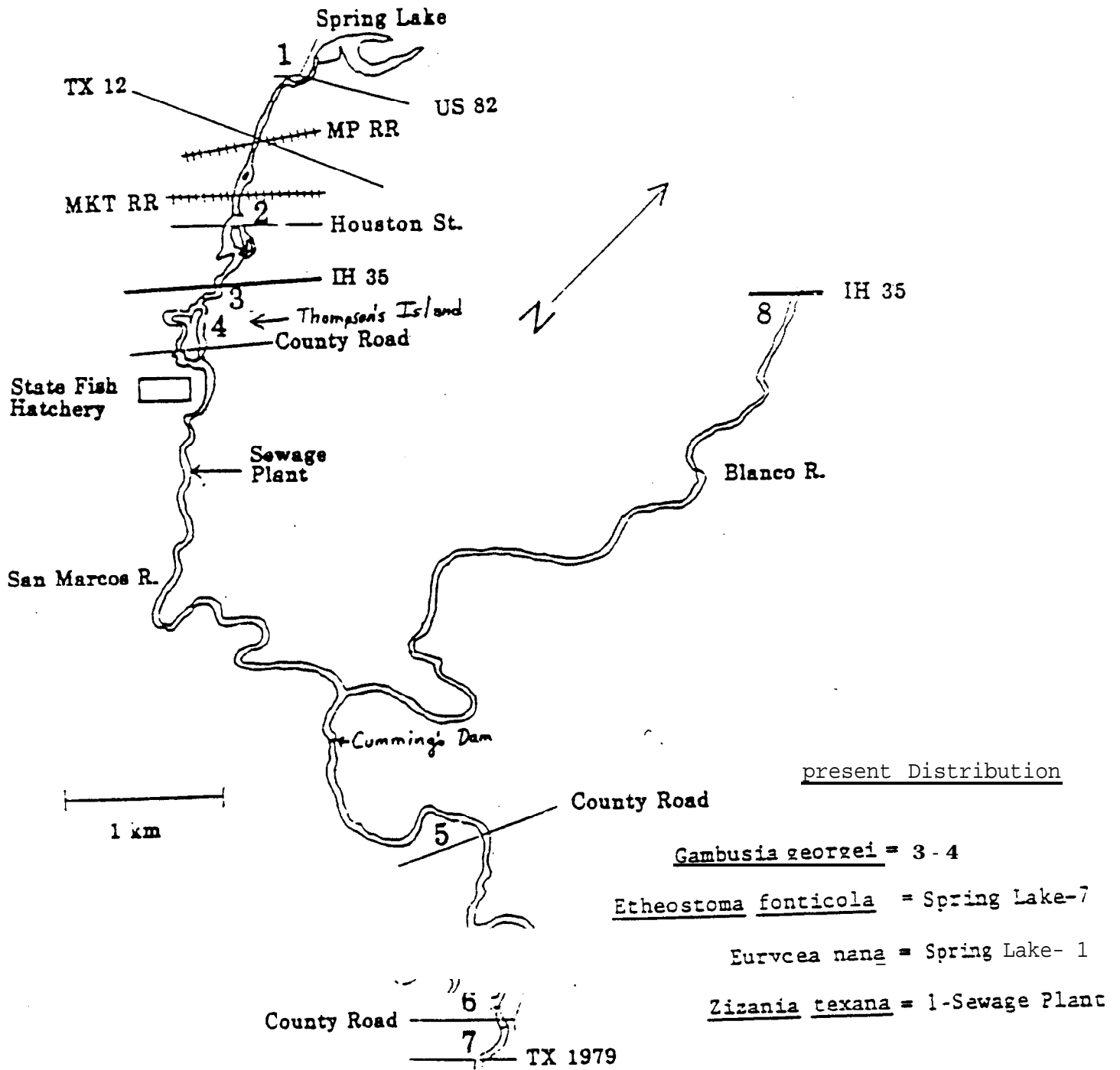


Figure 4

Present distribution in the San Marcos River of San Marcos gambusia (Gambusia georgei), fountain darter (Etheostoma fonticola), San Marcos salamander (Eurvcea nana), and Texas wildrice (Zizania texana). Numbers refer to collection stations of Edwards et al. 1980

this species occur (Hubbs and Peden 1969, Edwards et al. 1980).

Compared to *G. georgei*, *G. affinis* tends to show similar preferences for shallow, still waters, but differs strikingly from *G. georgei* in ability to colonize environments with greater temperature fluctuations. These environments include the partially isolated sloughs, intermittent creeks, and drainage ditches found in the upper San Marcos River, and in the nearby **Blanco** River and lower San Marcos River, as well.

To summarize, the San Marcos gambusia apparently requires: 1) thermally constant water; 2) quiet, shallow, open water adjacent to sections of moving water; 3) muddy substrates without appreciable quantities of silt; 4) partial shading; 5) clean and clear water; 6) food supply of living organisms, and 7) protection **from** severe flooding.

Food Habits: Nothing is known of the food habitats of *G. georgei*. Presumably, as in other poecillids, insect larvae and other invertebrates account for most of the dietary intake of this species.

Reproduction: There is little information on the reproductive capabilities of *G. georgei*. Two individuals kept in laboratory aquaria produced 12, 30 and 60 young, although the largest clutch appeared to have been aborted and did not survive (Edwards et al. 1980).

Hybridization: Hybridization between *G. georgei* and *G. affinis* was first noted by Hubbs **and** Peden (1969) and the production of hybrid individuals

between them has continued for many years without obvious introgression of genetic material into either of the parental species. Given the history of hybridization between these two species, this factor was not thought to be of primary importance in considerations of the status of G. georgei. It was thought that so long as the proportion of hybrids remained relatively low compared to the abundance of "pure" G. georgei, few problems associated with genetic swamping or introgression would occur (Hubbs and Peden 1969; Edwards et al. 1980). **However**, the most recent series of collections (Edwards, pers. comm.) taken during 1981-83 indicate that hybrid individuals may be many times more abundant than the pure G. georgei and that the hybrid individuals may now be placing an additional stress through competitive interference with the small native population of San Marcos gambusia.

Fountain Darter (Etheostoma fonticola)

Introduction and Background: Recognition of the fountain darter began with the inadvertent description **of** this species as Alvarius fonticola from specimens collected **from the** San Marcos River just below the confluence of the **Blanco** River in 1884 (Jordan and Gilbert 1886). The authors noted at that time that the species was abundant in the river. An additional specimen reported from the Washita River drainage of Arkansas by Jordan and Gilbert undoubtedly was misidentified (now presumed lost, and discussed under the section of this report entitled, "**Historical** Distribution").

Gilbert (1887), in the intended original description, redescribed the species and noted its occurrence only in the San Marcos River System.

Evermann and Kendall (1894) included an illustration of the species by E. Copeland which was designated the lectotype by Jordan and Evermann (1896). Because the "type" referred to by Jordan and Evermann was a lot containing four specimens, Collette and Knapp (1966) selected a lectotype from the U.S. National Museum collections of Etheostoma fonticola originally referenced by Gilbert (1887). The remaining three specimens included in this collection are now paralectotypes (Burr 1978).

E. fonticola is a small species of darter, usually less than 25 mm standard length (SL), and is mostly reddish brown in life. The scales on the sides are broadly margined behind with dusky pigment. The dorsal region is dusted with fine specks and has about 8 indistinct dusky cross-blotches. A series of horizontal stitch-like dark lines occur along the middle of the sides, forming an interrupted lateral streak. Three small dark spots are present on the base of the tail and there is a dark spot on the opercle. Dark bars appear in front of, below, and behind the eye. The lower half of the spinous dorsal fin is jet-black; above this appears a broad red band, and above this band the fin is narrowly edged with black. The fountain darter exhibits sexual dimorphism in four

morphological characters: banding pattern, spinous dorsal fin coloration, genital papillae and pelvic and anal fin nuptial tubercles (Jordan and Gilbert 1886; Gilbert 1887; Jordan and **Evermann** 1896, 1900; Strawn 1955, 1956; Collette 1965; Schenck and Whiteside 1976c).

Although the fountain darter traditionally was believed to be the most advanced (specialized) darter, the basis for this was the analysis of a very limited subset of characteristics which appear to be highly influenced by environmental factors such as temperature (Bailey and Gosline 1955; Collette 1962). The subgenus Microperca, to which E. fonticola belongs, is still thought to be the most derived subgenus of Etheostoma. The evolutionary history of this group is presumed to involve an early separation of the presently recognized E. proeliare and E. microperca groups followed by a later isolation of a subset of an E. proeliare-like ancestor. This. E. proeliare-like ancestor survived and became the presently recognized E. fonticola in only the San **Marcos** and Comal Rivers (Bailey and Gosline 1955; Collette 1962, 1965; Page and Whitt 1972; Collette and Banarescu 1977; Page 1974, 1977; and Burr 1978).

Habitats: In general, E. fonticola prefers vegetated stream-floor habitats with a constant water temperature. The fish prefers mats of the **filamentous** green **alga** (Rhizoclonium sp.) over other aquatic plants and is very rarely

found in areas lacking vegetation. Young fish consistently have been collected in heavily vegetated, backwater areas of the San **Marcos** River where flow is negligible, whereas adults occur in all suitable habitats including riffles (Schenck and Whiteside 1976a).

In addition to inhabiting the San **Marcos** River, the fountain darter also is found in the Comal River, which begins at numerous springs collectively called Comal Springs that originate from the Edwards Aquifer within the City of New Braunfels, Comal County, Texas (Fig. 2).

The **Comal** River flows east approximately 5 km before emptying into the Guadalupe River, making it the shortest river in Texas and also the shortest river in the United States carrying an equivalent amount of water (Texas Almanac 1973). Blieders Creek, about 11 km long and dry except after rains, joins the **Comal** River at the headsprings located on the north side of the city. A short distance downstream from the headsprings, another tributary, Dry Comal Creek, enters the **Comal** River from the southwest. The upper end of the river has been dammed and developed into a municipal recreational area, **Landa** Park.

Comal Springs has the greatest mean discharge of any springs in the southwestern United States (George et al. 1952). The mean discharge during the period 1928-1972 was  $7.8 \text{ m}^3/\text{s}$  (275.4 cfs) (Edwards Underground

Water District 1974). The maximum recorded discharge of  $15.1\text{m}^3/\text{s}$  (533.2 cfs) occurred in October 1973. The springs ceased flowing from June until November 1956 when they began flowing again at a slow rate (U.S. Army Corps of Engineers 1964). At that time, all major springs in the **Balcones** Fault Zone had ceased to flow, with the exception of San Marcos Springs which had decreased their flow substantially. Discharge from Comal Springs from March 1973 to February 1975 had a mean of  $11.6\text{m}^3/\text{s}$  (409.6 cfs) and ranged from  $9.5\text{m}^3/\text{s}$  (335.5 cfs) in May 1973 to  $15.1\text{m}^3/\text{s}$  (533.2 cfs) in October 1973. The mean annual water temperature of Comal Springs is 23.4 C (George et al. 1952).

To summarize the fountain darter apparently requires: 1) thermally constant waters, 2) undisturbed stream floor habitats with riffles and pools, 3) mats of filamentous algae for cover, 4) **clear and** clean water, 5) food supply of living organisms, 6) flowing water, and 7) protection from severe floods.

Food and Feeding **Habitats**: Based on percent frequency of occurrence in sampled stomachs, fountain darters < 19.2 mm SL feed primarily on copepods, darters between 19.2 and 29.5 mm SL feed mainly on dipteran and ephemeropteran larvae, and darters > 29.6 mm SL prefer ephemeropteran larvae.

Food habits of fountain darters in Spring Lake differ from the food habits of darters in the San Marcos River. Casual observations indicate that the overall invertebrate community in Spring Lake is different from the community in the river, which could explain the observed differences in food habits of darters in these two areas on the basis of availability of food items.

Fountain darters feed primarily during daylight and demonstrate selective feeding behavior. Those held in an aquarium feed on moving aquatic invertebrates while disregarding immobile ones, suggesting that these darters respond to visual cues. They apparently do not chase food organisms but remain stationary until prey items move to within approximately 3 cm (Schenck and Whiteside 1976b).

Population Estimates: Schenck and Whiteside (1976a) estimated the total number of E. fonticola in the San Marcos River to be approximately 103,000. The only other population estimates of this species are given in the book of rare and endangered wildlife of the United States (U.S. Dept. of Interior 1973b). The estimate is approximately 1,000 E. fonticola for ~~the~~ San Marcos River, but the method of estimation was not given.

No population estimates of E. fonticola are available for the Comal River. However, because of low availability of suitable springrun habitat, there are fewer fountain darters in the **Comal** River than in the San Marcos River.

Reproduction: The reproductive activities of fountain darters were first described by Strawn (1955, 1956) who noted that E. fonticola are headwater darters which breed in the relatively constant temperature of the San Marcos River. He further recorded in his publications that fountain darters appear to spawn year-round and that the parents, after &positing

eggs in vegetation, provided no further care to the young. After hatching, the fry were never free swimming, in part due to the reduced size of their swim bladders as in other etheostomatine fishes. Strawn (1956) also included a photograph of a breeding male in its nuptial coloration in his discussion of the reproduction of this species. Males develop nuptial **tubercles** on their pelvic and anal fins (Collette 1965) and the sexes are dimorphic in this respect. Tubercles on darters are thought to stimulate gravid females or to assist in maintaining the spawning position within the vegetation (Collette 1965).

Fountain darters have been artificially hybridized with a number of other species including: E. caeruleum, E. chlorosomum, E. euzonum, E. juliae, E. lepidum, E. spectabile, Peraina caprodes and P. sciera. Procedures for artificially stripping eggs and milt of fountain darters and a discussion of the artificial hybridization and the resulting low survival of the various hybrid combinations appear in Strawn and Hubbs (1956), Hubbs and Strawn (1957a,c), Hubbs (1958, 1959), Hubbs and Laritz (1961), Hubbs (1967), and Distler (1968). These studies demonstrated that male fountain darters produce little milt and that which is produced tends to be invisible (Hubbs and Strawn 1957b, Hubbs 1958).

Schenck and Whiteside (1976c) reported that natural populations of fountain darters have two temporal peaks of ova development, one in August and the other in **late** winter to early spring. Therefore, fountain darters apparently have two major spawning periods annually. The monthly

percentages of females with ovaries containing at least one mature ovum also demonstrate the two annual spawning peaks. However, females containing at least one mature ovum have been collected **throughout** the year, further suggesting year-round spawning. The ovary weight/body weight relationship and the testis width/square root of total length relationship also indicate the **two peak** spawning periods (Schenck and Whiteside 1976c).

Most darters spawn in the spring or early **summer**. However, populations of E. lepidum and E. spectabile which live in areas with slight annual water temperature variation extend their breeding periods **considerably** (up to **10-12** months)(Hubbs and Strawn **1957b**, Hubbs et al. 1968). The extension of the breeding season of E. spectabile throughout the summer is also known for a population inhabiting the Guadalupe River below Canyon Reservoir where releases from the bottom of the reservoir moderate water temperatures, especially during summer months (Marsh 1980). Since E. fonticola also lives in a relatively constant temperature environment, it is not especially surprising to find that this species spawns throughout the year as was originally **suggested** by Strawn (1956).

The mean diameter of mature ova (1.10 mm) from E. fonticola apparently is not correlated with length of the fish. Based on 74 E. fonticola which contained mature ova, the mean fecundity was 19, which **is** less than in other darters. This low fecundity is probably compensated for by repeated spawnings of small groups of eggs throughout the year. It is not **known** how many ova are spawned annually by each E. fonticola.

E. fonticola provides no **parental** care to the ova (Strawn 1955).

Dowden (1968) found **fountain** darter eggs attached to moss and to algae and these eggs hatched in aerated aquaria.

Sex determination of E. fonticola (325 males and 234 females) revealed a sex ratio of **1.39:1** (Schenck and Whiteside 1976c).

Historical Distribution: The original range of E. fonticola includes the San **Marcos** and Comal Rivers in Texas (Jordan and Gilbert 1886, Gilbert 1887, **Evermann** and Kendall 1894, Jordan and **Evermann** 1896, Ball et al. 1952, Hubbs et al. 1953, Hubbs 1954, Kuehne 1955, Strawn 1955, Hubbs 1957, Hubbs and Strawn **1957b**, Schenck and Whiteside 1976a). Fountain darters also have been reported from four other localities, three in Texas and one in Arkansas. The collection **from** Dickinson Bayou, Harris County, Texas, reported by **Evermann** and Kendall (1894) appears to be a misidentification (and perhaps a confusion of field locality data) **from** Evermann's 1891 collections in Texas (Hubbs 1982).

Charles T. Menn of the Texas Parks and Wildlife Department apparently mistakenly recorded the presence of E. fonticola in his two most downstream stations in the **Nueces River** near Corpus **Christi**, Texas (Texas Parks and Wildlife Department 1965). The validity of these records apparently was questioned in 1965 and the fishes identified as fat sleepers, Dormitator **maculatus**, a common estuarine species (C. Hubbs, University of Texas, pers. **comm.** 1983).

The Washita River, Arkansas, report of E. fonticola (Jordan and Gilbert 1886) is the only extra-Texas record of fountain darters. These specimens, now lost from the Smithsonian collections, are presumed to be E. proeliare, which were misidentified due to the early confusion in the taxonomy and systematic6 of the subgenus Microperca to which both E. proeliare and E. fonticola belong.

In 1884, Jordan and Gilbert (1886) collected the type specimens of E. fonticola in the San **Marcos** River from immediately below the confluence of the **Blanco** River. Fountain darters have been found sporadically in reduced numbers to approximately 3 km below this point.

**Evermann** and Kendall (1894) collected 43 specimens of E. fonticola in the Comal River in 1891, the first collection record for that locality. Hubbs and Strawn (1957a) collected this species from the **Comal** River in 1954, the last collection record for that locality of the original population.

During March 1973 through February 1975 Schenck and Whiteside (1976a) spent 300 man-hours sampling the **Comal** River but collected no E. fonticola. They proposed three possible reasons why E. fonticola was absent from the Comal River. First, the Comal River was treated with **rotenone** in December 1951. Many specimens of desirable fishes, including E. fonticola, were seined and held in a protected area until the **rotenone** dissipated (Ball et al. 1952, C. Hubbs, **pers. comm.**). This

procedure reduced the number of E. fonticola but apparently did not cause **their immediate** elimination since this species was last collected in the **Comal** River in 1954. Second, Comal Springs ceased flowing for five months in 1956, which probably caused drastic temperature fluctuations in the remaining pools of water. Since E. fonticola occupies areas with constant water temperature, temperature fluctuations possibly caused the elimination of this species. Third, but less likely, a flood from Blieders Creek inundated the entire Comal River in the spring of 1971 and may have caused their elimination.

From 1974 until 1981 a stock of E. fonticola taken from the San **Marcos** River near the **IH** 35 crossing was cultured at the Federal facility at Dexter, New Mexico, to ensure against a catastrophic loss of this species.

Present Distribution: The present distribution of E. fonticola in the San **Marcos** River is well documented (e.g., Schenck 1975 and Fig. 4).

B. G. Whiteside and J. R. Schenck released 457 adult E. fonticola into the headsprings area of the Comal River, **Landa** Park, New Braunsfels, Texas, during 1975 and early 1976. They found five offspring a short distance below the headsprings area on June 18, 1976. An established reproducing population now occupies the upper Comal River (Fig. 5).

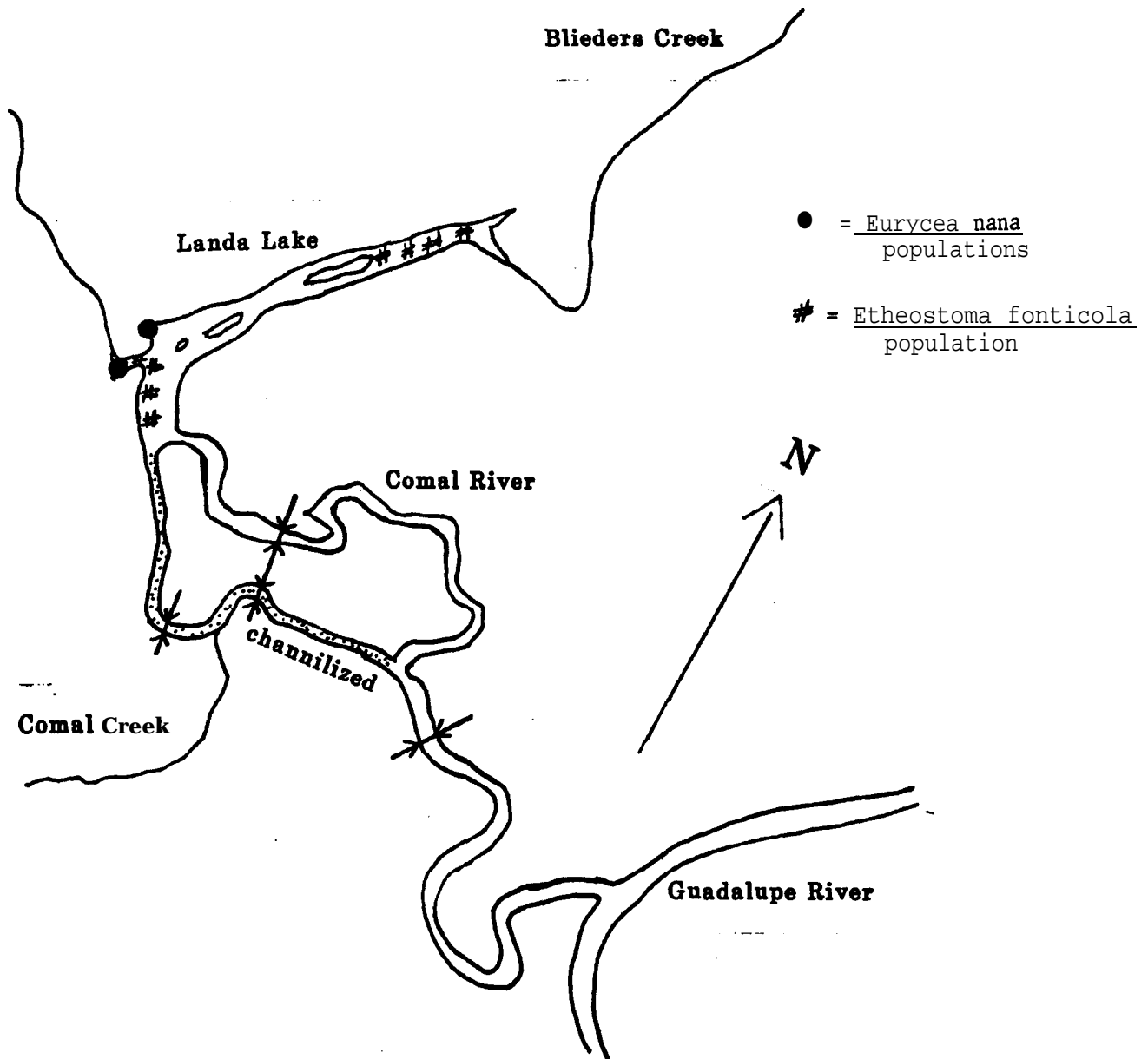


FIGURE 5. Map of Comal River, Comal County, Texas. The present known distribution of Etheostoma fonticola and Eurycea nana in the Comal River is in the headwaters portion (Landa Lake portion) in the northern half of Landa Par

San Marcos Salamander (Eurycea **nana**)

Introduction and Background: The San Marcos salamander (Eurycea **nana**) is a member of the family Plethodontidae (lungless salamanders). The various species of Eurycea are known as brook salamanders. E. **nana** is a neotenic form and retains its external gills (the larval condition) throughout life. The salamander does not leave the water to metamorphose into a terrestrial form, but becomes sexually mature and breeds in the water. The specific name **nana** is from the Greek nanos or Latin nanus, meaning dwarf, referring to the small adult size of these salamanders (Brown 1967).

This salamander is listed by the State of Texas as protected **nongame** (threatened) and by the U.S. Fish and Wildlife Service as threatened.

**E. **nana**** is restricted to the headwaters of the San Marcos and Comal Rivers and the potential for these springs to cease flowing periodically or completely is but one factor for listing this species as threatened.

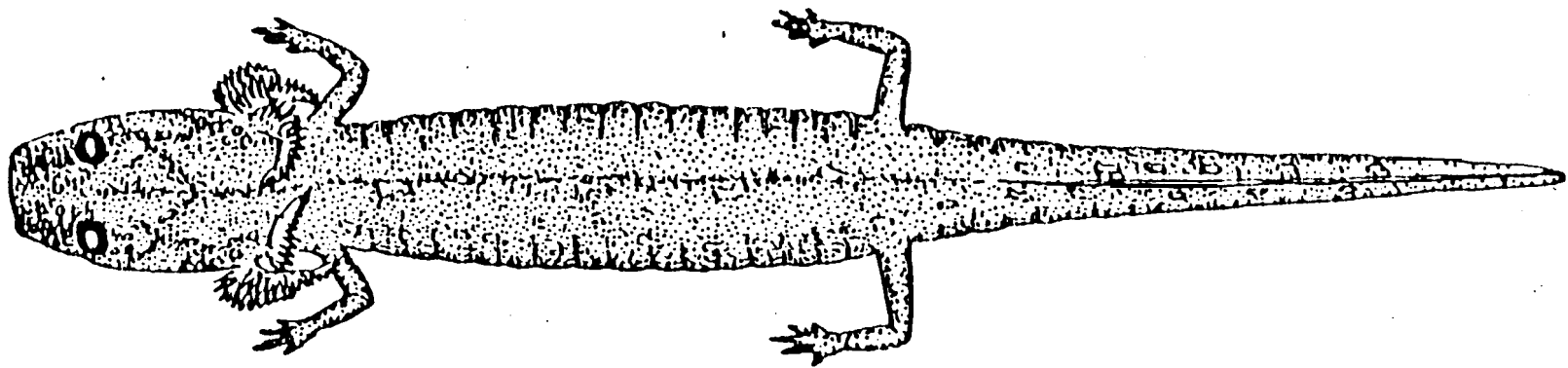
Description: On June 22, 1938, C. E. Mohr collected a series of 20 specimens from San Marcos Springs. The specimens were sent to Sherman C. Bishop who described E.**nana** as "a small, slender, neotenic species uniformly light brown above with a dorsolateral row of pale spots on either side

of the mid-line; yellowish white below; with 16 or 17 **costal** grooves.

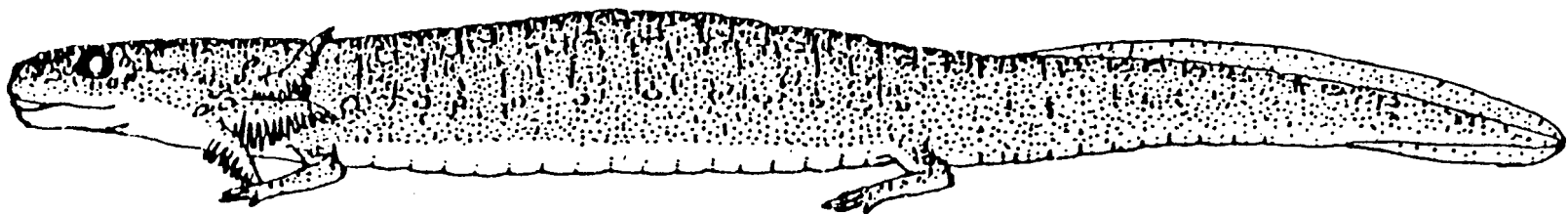
E. nana differs from E. neotenes, the only other species of the genus from the general locality, in its smaller size, its uniformly light brown dorsal coloration relieved only by a few small light spots, and in its more slender form and longer, more slender toes." (Bishop 1941).

Prominent external features of the small (up to 59.6 mm total length), slender salamander are its moderately large eyes with a dark ring around the lens, its well developed and highly pigmented gills, its relatively short slender limbs with four toes on the **forefeet** and five on **the** hind feet, and its slender tail with well developed dorsal fin (Figure 6). Compared to other **neotenic** Eurycea from Texas, the San Marcos salamander is smaller and more slender, has a different coloration, has larger eyes relative to the size of its head, has a greater number of **costal** grooves, and has fewer pterygoid and premaxillary teeth. Detailed morphological descriptions of this species are found in Bishop (1941, **1943**), Baker (1957, **1961**), Mitchell and Redell (**1965**), Schwetman (1967) and Tupa and Davis (1976).

Historical Distribution: Baker (1961) listed the springs where E. nana was found as "**Comal** Springs, San Marcos, Hays County, Texas," obviously referring to San Marcos Springs. Bogart (1967) studied the life histories and chromosomes of Texas Eurycea on the Edwards Plateau. Based on his



1 (Dorsal view)



2 (Lateral view)

Figure 6. Drawing of Eurycea nana (modified from Schwotman 1967)

karyotypes, he indicated E. nana populations occurred at the following places in addition to San **Marcos** Springs: **Sabinal** River population, 8.9 km north of **Vanderpool, Bandera** County; Mountain Home population, headwaters of the river feeding into **the** fish hatchery in Mountain Home, Kerr County; and **Kerrville** population, 8 and 11 km west of Highway 16 beside **RR** 1273, Kerr County. Sweet (1978) indicated that a population of Eurycea which inhabits **Comal** Springs in New Braunfels is very similar to E. nana and is probably conspecific. Sweet also stated that all of the epigean populations of Eurycea on the Edwards Plateau apart from those in fault-zone springs should be considered as E. neotenes.

Bogart (1967) is the only reference listing E. nana in locations other than San **Marcos** Springs and Comal Springs. Bogart's work has not been published. Therefore, the lack of opportunity for specialists in **the** field to review and comment on his findings leave them open to question. Sweet (1978) has provided **the best information** regarding historic distribution. Tupa and Davis (1976) delineated in considerable detail **the** range of E. nana. They felt the only stable population onana, occurred along the shallow area adjacent to the northern bank of Spring Lake, especially in the uppermost region **of** the lake in front of the **Aquarena** Springs Hotel.

Present Distribution: On November 24, 1975, a sampling program was started on the largest fissures that constitute San **Marcos** Springs (Longley 1978). The sampling involved placing a **500-micrometer** mesh net over the

outlet from one of the major springs in Spring Lake dubbed "Pipe Spring" since it had been diverted via pipe into the show area of Aquarena's '\*Submarine Theater.' The concrete base over the spring opening had been undercut by action of floods in recent years and this allowed material from the lake bottom in the vicinity of the spring to be sucked into the outflow from the spring by a venturi. Small organisms such as E. nana could work their way between the rocks surrounding the spring opening until they were caught in the flow from the spring and then be carried into the net along with subterranean organisms. E. nana were found in most samples. All sizes were common, but juveniles were most often collected. E. nana also was found in most samples taken from "Deep Spring" in Spring Lake. The conclusion is that E. nana occurs abundantly in close proximity to the major spring openings and also in the dense mats of the filamentous alga Lyngbya sp. found along the north side of the headwaters in front of the hotel.

Habitats and Requirements: The salamander is predominantly located in shallow spring areas on the uppermost (northernmost) portion of Spring Lake on a limestone shelf in an area immediately in front of **Aquarena** Springs Hotel (Figure 4). The substrate in this area is sand and gravel interspersed with large limestone boulders. Concrete banks in front of the hotel and boulders in shallow (1-2 m) water support a lush adherent

growth of the aquatic moss Leptodictyum riparium. Interspersed with the moss and blanketing the shallow sandy substrate are thick hairy mats of a coarse, filamentous blue-green alga (Lyngbya sp.), the dark **reddish-brown** color of which almost perfectly matches the dark dorsal coloration of the San **Marcos** salamander.

Spirogyra sp. and a few other species of larger filamentous green algae, as well as the carnivorous angiosperm Utricularia **gibba**, are present in small amounts in the aquatic moss. A wide variety of rooted aquatic macrophytes occur on the periphery of the salamander habitat at 1-3 m depths. These macrophytes include Sagittaria platyphylla, **Myriophyllum** brasiliense, Ludwigia **repens** and Vallisneria americana. In deeper water, Cabomba caroliniana and Egeria **densa** become the dominant macrophytes of the mud and detritus-laden benthic region.

The salamanders are abundant within the wiry mesh of the aquatic moss and the hairy mats of Lyngbya **sp.** in the shallow headwaters area. Small mats of Lyngbya **sp.** occur also in the **immediate** vicinity of some of the larger and much deeper springs in the lake and could be the source of specimens collected there in recent years. Sandy substrates devoid of vegetation and muddy or detritus-laden substrates with or without vegetation are apparently unsuitable habitats for E. nana. Specimens occasionally are collected from beneath stones in predominantly sand and

gravel areas. In view of the abundance of predators (primarily larger fish, but also crayfish, turtles and aquatic birds) in the **immediate** vicinity of the springs, protective cover such as that afforded by the moss and cyanophycean alga is essential to the survival of the salamander. A plentiful food supply for the salamander also is harbored by this vegetation.

Flowing water is apparently a prerequisite for suitable *E. nana* habitat, as no specimens were found in still water areas of the lake and river. The flowing spring waters in the principal habitat are slightly alkaline (**pH 7.2**), stenothermal (**21-22°C**), and clear. In the springs area, the oxygen content of the waters is about **4 mg/l** or greater, indicating the thermally constant waters are about 40-50 percent saturated with oxygen. Methyl orange alkalinity (due entirely to bicarbonates) measured **220-232 mg/l** and the specific conductance measured **510-535 micromhos/cm** in **the habitat** (Tupa and Davis 1976). In captivity, the salamanders demonstrate an intolerance for temperatures of **30°C** or greater. Oxygen consumption by the species was greatest at water temperatures of **25°C** as compared with 20 or **30°C** (Norris et al. 1963).

The headwaters of the San **Marcos** River at the northernmost end of Spring Lake near the hotel tend to be protected from floodwater action. Protection from scouring by floods undoubtedly contributes to the continued survival of the salamander population since the salamander is not a

strong swimmer and the loss of protective vegetation and food supply could be critical.

To summarize, the San **Marcos** salamander apparently requires: (1) thermally constant waters; (2) flowing water; (3) clean and clear water; (4) sand, gravel, and rock substrates with little mud or detritus; (5) vegetation for cover; (6) food supply of living organisms; and (7) protection **from** floods.

Associated Species: Occupying the same habitat as **E. nana** is the fountain darter, which displays many of the same feeding and protective concealment habits of **the** salamander. They, unlike other fishes in the area but like the salamanders, are found within the aquatic moss growths and myngbya s , as well as beneath and alongside stones. Like the fountain darters, the salamanders in the lake habitat eat amphipods.

In association with the salamander and darter in the moss and algal vegetation are crayfish (Cambarus sp.) of varying sizes, two species of small freshwater shrimp (Palaemonetes spp.), many tendipedid larvae, a variety of other insect larvae, a very large number (particularly in the moss) of amphipods (Hyalrella azteca), water mites, and many small aquatic snails. **Leeches** (Placobdella sp. and others) and planarians (Dugesia sp.) are also numerous, especially in samples **taken** over rocky substrates.

Most larger associated species are predators and occur in the vicinity of the salamander habitat, including several species of sunfishes and cichlids which feed on insect larvae, amphipods, terrestrial isopods, aquatic snails, freshwater shrimp, fountain darters, and San **Marcos** salamanders. Turtles such as stinkpots (Sternotherus odoratus) occasionally are present in the salamander habitat as are bullheads (Ictalurus **sp.**) and largemouth bass (Micropterus salmoides).

Introduced swans (Cygnus olor) and domesticated mallard ducks (Anas platyrhynchos) in the lake feed on the aquatic moss and Lyngbya **sp.** These birds roost nightly on the sidewalk alongside the salamanders' principal habitat (Tupa and Davis 1976).

Food Habits: Salamanders in laboratory aquaria fed on amphipods. Stomach content analyses of 80 preserved specimens revealed the salamander's diet in its natural habitat included amphipods and tendipedid (midge fly) larvae and pupae; other small insect pupae and naiads and small aquatic snails were found in lesser **numbers**. Small amounts of Lyngbya **sp.** and grains of sand occasionally were present, apparently as incidental items ingested along with principal food items. Feeding behavior observed in the laboratory was similar to that of the fountain darter, in that the salamanders did **not actively** pursue their prey. Salamanders remained stationary

until the prey items were near their head, then abruptly snapped forward while opening their mouth to engulf food items. This suggests they respond either to visual or vibrational cues from living prey.

**Reproductive Characteristics:** Male E. nana reach sexual maturity (possess at least one full darkly-pigmented lobe in each testis) only after attaining a snout-vent length of 19 mm (35 mm total length). All males with snout-vent lengths greater than 23.5 mm (40-45 mm total length) were mature, possessing darkly-pigmented testes with one to three lobes (Tupa and Davis 1976). Sperm were found in the testes of all mature males collected from October to May and in the Wolffian ducts of Certain males from October to June (except for January and March) in an investigation by Mackay (1952) which did not include the months of July and August. Mackay found large numbers of spermatozoa in the Wolffian ducts in November and the ducts were in a distended condition in June, leading her to postulate a breeding season in June and possibly another in the fall.

Salamanders had four classes of ova in the oviducts: very small clear ova,, small opaque-white ova, small yellow ova, and large yellow ova. Females carrying large yellow ova (1.5-2.0 mm in diameter) were considered gravid and presumably ready for oviposition. Large yellow ova were present in females with snout-vent lengths greater than 20.0 mm (35 mm total length). Females with a snout-vent length  $\geq$  26 mm carried 1 to 19 large yellow ova, possibly indicating oviposition of only a portion

of the larger eggs. Large yellow ova were present in some females in nearly every month of the year (Tupa and Davis 1976).

Courtship and egg deposition by E. nana has not been reported, and no eggs have been collected from the habitat. However, courtship and oviposition were observed for closely related E. neotenes. Eggs of this species were deposited on plant material, stones, and the bottom of a glass bowl about 24 hours after courtship. Eggs **developed** to hatching in 25 days (Bogart 1967). Most, if not all, Eurycea breed in running water of brooks, caves, or springs. In most cases, adherent eggs are deposited singly on the bottom and sides of stones, or on aquatic vegetation.

A total of seven small juveniles of E. nana still possessing yolk on the venter were collected in February, May and June 1968. Juveniles of less than 12 mm total length were collected from February through October (Tupa and Davis 1976). Bogart (1967) found wry small nana in September, December, March, April and June, but noted they were most common in the late spring and early **summer**. He postulated that **the** salamander breeds most of **the** year with a peak in late spring.

The structure of the E. nana population is remarkably uniform throughout the year. In all seasons juvenile specimens (snout-vent lengths usually less than 15 mm) of undetermined sex represented about

45 percent of the total population. Larger juveniles (about 15-20 mm snout-vent length) of undetermined sex represented about 30-40 percent of the population. Mature males (snout-vent lengths 19 mm and greater) represented about 10-15 percent and gravid females (snout-vent lengths 20 mm and greater) about 4 percent of the total (Tupa and Davis 1976).

To summarize, most evidence suggests breeding occurs throughout the year with a possible peak about May and June.

Other Known Biological Aspects: The San **Marcos** salamander is capable of altering its dorsal coloration between light tan to dark brown in accord with **the** lightness or darkness of the substrate. This color change is accomplished by migration of pigment in melanophores, giving them the appearance of expanding or shrinking (Schwetman 1967).

The external gills of the salamander expand and appear bright red from increased blood flow in cool water of low oxygen content. The **bushy** red gills are prominent on individuals when collected from the springs, but they **show** marked reduction, almost to the point of apparent resorption when specimens are kept in well-oxygenated aquaria (Tupa and Davis 1976).

The **number** of **E. nana** in the uppermost portion of Spring bake is between approximately 17,000 and 21,000 individuals (Tupa and Davis 1976).

Texas Wildrice (Zizania texana)

Introduction and Background: Texas **wildrice** (Zizania texana) is of special interest because of its rarity and its problematical relationship to other species of Zizania.

Z. texana is restricted to a 2.4 km (~~1.5-mile~~) length of the headwaters of the San Marcos River within the city limits of San Marcos. Formerly, the species also occurred at **the** headwaters of the river in Spring Lake (Watkins 1930, Devall 1940, Terrell et al. 1978).

The first documented collection of Z. texana was by G. C. Nealley in August 1892 (U.S. National Herbarium sheet 979361) and was **labelled** Z. aquatica, thus Nealley apparently did not suspect it to be different. A later collection (US 1611456) by **Ena** A. Allen on July 10, 1921, was **labelled** Z. texana, apparently by A. S. Hitchcock long after its **collection**. Both of these collections came from the San Marcos River.

The discovery and recognition of Z. texana as a distinct species was by W. A. Silveus, an attorney and amateur botanist living in San Antonio, Texas. In a letter (preserved with the holotype in the U.S. National Herbarium) dated April 4, 1932, Silveus wrote to Agnes Chase of the National Herbarium regarding one of his collecting trips to the San **Marcos** area. He noted that the grass grew in water from 0.3 - 1.2 m deep some distance from the stream bank and the flowering part of the **culm** of many plants reached 0.3 - 0.6 m above the water. **He** further noted

that leaves were as much as 1.5 m long, 8-10 mm wide at the base and 15-20 mm wide above. In a subsequent letter to Mrs. Chase dated 7 November 1932, Silveus noted that Texas **wildrice** apparently bloomed from April to November and indicated that local residents said that blooms were present throughout the year when warm. The distribution of the species at that time encompassed several acres on Spring Lake and downstream.

The type collection of Z. texana is in the U.S. National Eerbarium: "W. A. Silveus 518, April 1932, floating in San **Marcos** River near San **Marcos**, Hays Co., **Texas** (holotype US 1537174; isotype US 1720531)". It may be inferred from Silveus' letter of April 4, 1932, that the type collection was gathered on April 3, 1932.

The morphology and taxonomy of Z. texana are described by Hitchcock (1933), Silveus (1933), Correll and Johnston (1970) and Terrell et al. (1978).

**Wildrice Species:** In this report, the use of the common name "wildrice," follows Correll and Johnston (1970). **Dore** (1969) accepts as distinct species southern **wildrice** (Z. aquatica L.) and northern **wildrice** (Z. palustris L.). The former is concentrated along the Atlantic Coastal Plain westward to Louisiana and extends into southern New England and westward into Wisconsin. The latter is in New England, eastern Canada, and the Great Lakes region westward into Manitoba. Northern **wildrice**

has long been known as an Indian food (it usually has larger grains than southern wildrice) and recently was brought into cultivation in Minnesota and Canada. Another related species, *Z. latifolia* (Griseb.) Turex, ex Stapf, is native to eastern Asia.

Little was known about the taxonomic status of *Z. texana*. Dore (1969) called it a "dubious species" and suggested that its underground parts might have been confused with the rhizomes of *Zizaniopsis miliacea* (Michx.) Doell & Aschers. Dore (letter to Terrell, 26 Nov. 1974) explained that some years ~~ago~~ he requested plants of *Zizania texana* from a Texas correspondent and was sent rhizomes which grew into *Zizaniopsis miliacea*.

During a recent study, W. Emery (**pers. comm.**, Southwest Texas State University) found *Zizaniopsis miliacea* along banks of the San Marcos River and at two sites immersed in the river, with **streaming culms** and leaves. **One** plant was grown to maturity from rhizomes. Emery found that *Zizaniopsis miliacea* may be distinguished vegetatively from *Zizania* by its bluish coloration, leaf anatomy, and large rhizomes. Terrell and Robinson (1974) noted differences also in the arrangement of the stellate cells in the leaf sheath, and after comparing *Zizania* and *Zizaniopsis* in several important reproductive and vegetative characters, concluded that they belonged in separate subtribes.

The origin of Z. texana poses interesting but difficult problems. In view of its morphology, we suppose that Z. texana evolved its unique characteristics over a substantial period of time. It may have evolved in geographic isolation, as there are no other natural populations of any Zizania **taxon** in Texas. The nearest natural populations of Z. aquatica are in southern Louisiana, about 640 km (400 miles) to the east and are quite different morphologically from Z. texana. They are giant grasses (4 m high), with only their lower **culms** immersed and with leaves 3-5 times broader than those of Z. texana. The nearest populations of Z. palustris are several hundred kilometers to the north and northeast in Missouri, Kansas, and Arkansas.

Associated Species: In the upper 0.4 km of the portion of the river inhabited by wildrice, associated species include Potamogeton illinoensis, Vallisneria americana, Sagittaria platyphylla, G. Sm., and Hydrilla verticillata. Throughout most of the remaining 2.0 km of the habitat, Texas **wildrice** is most frequently found in isolated clumps, and competition from other species is apparently of minor importance.

Ecology and Distribution: At the time of its discovery, Z. texana was abundant in the San **Marcos** River, contiguous irrigation ditches, and Spring Lake. Considerable effort was required by the irrigation company to keep its luxuriant growth under control (Silveus 1933). Thirty-four

years later its abundance had been reduced drastically. Emery (1967) found only one plant in Spring Lake, no plants in the uppermost 0.8 km of the San Marcos River, and only scattered plants in the next 2.4 km. In 1970, Emery surveyed the lower reaches of the river by boat but did not find any **wildrice**.

In 1976, Emery (1977) again **checked** on the abundance of **wildrice** in the upper river. Utilizing a floating 1 m<sup>2</sup> **frame** to measure the area of vegetative dominance, he estimated that **wildrice** plants **covered** 1,131 m<sup>2</sup> of river habitat. The highest **concentrations** were in the extreme upper and lower segments of the 2.4 km length of the river. He did not find any **wildrice** in Spring Lake (Figure 4).

Plants of Z. texana form large **clones** or masses firmly rooted in the gravel bottom of the river. Culms and leaves are completely **immersed** and long-streaming in the swift current. Plants are **geniculate** and **produce** roots from the lower nodes. **Silveus' description** (1933) and his photograph **accompanying** his article indicate that formerly, when there was less **human** disturbance, **culms** and panicles projected as **much** as **one** meter above the water. Presently, however, flowering plants are rarely seen, and when present, do not extend very far above the surface. Plants often grow in the swiftest **currents** of the shallow areas near the middle of the river. Other plants are in water 2-3 m deep, and the streaming leaves remain below the surface, the **clear** water allowing passage of **sufficient** light for photosynthesis.

To summarize, the Texas **wildrice** apparently requires: 1) thermally constant waters, 2) flowing waters, 3) undisturbed stream floor habitats, 4) unimpeded **inflorescence** for sexual reproduction, 5) **clear** and clean water, and 6) protection from floods.

Observation in Cultivation: Three small clumps of Z. texana collected from the San Marcos River were brought to Beltsville, Maryland, by Terrell in September 1973 and were transplanted into large plastic pots containing potting soil. They were then placed in a 1 X 3 m tank of tap water in a greenhouse and were maintained with a few centimeters of water over the soil surface in the pots. The water in the tank was regulated at a constant temperature of approximately 23 C and was kept circulating (but not aerated) by an electric pump. Water was replaced at monthly or bimonthly intervals.

By December 1973, only one of the three plants had survived. This plant, instead of growing immersed as in nature, produced several erect, aerial culms up to 1 m high. The plant flowered abundantly from January 1974 through the summer of 1974, but was somewhat less robust. The plant eventually was divided into four. In autumn-winter 1974, these plants were attacked by two-spotted mites (Tetranychus urticae Koch) and were considerably weakened. By January 1975, the plants were dead. It is suspected that the mites were not entirely responsible for the wildrice demise; environmental factors apparently were not favorable for growth.

During 1974 about 80 seeds were obtained from self-pollination of the plants in the greenhouse. These seeds apparently were of normal size compared to others in the herbarium of the Patuxent Wildlife Research Center, Laurel, Maryland. Some seeds germinated but consistently failed

to survive after reaching a few centimeters length. Seedlings grown in San **Marços** River water also died. Further attempts were made in 1975 and 1976 to grow **Z. texana** in the greenhouse tank at Beltsville, but the seedlings died even in the presence of supplemental light. Apparently **Z. texana** needed special **requirements** not adequately met at Beltsville. In contrast, seedlings of **Z. aquatica** and **Z. palustris** were grown to maturity under these **same** conditions.

In 1975, Emery moved four clones of **Z. texana** from their river habitat to a raceway supplied with **constant** temperature, artesian well **water** on the campus of Southwest Texas State University in San **Marços**, where it was possible to regulate both the **velocity** and depth of the water. The four **clones** produced vigorous growth and abundant foliage. Their growth form was altered dramatically. The **decumbent culms** and **submerged** leaves **characteristic** of the river clones changed to **erect culms** with emergent aerial leaves. **Inflorescences** formed and **cross** fertilization of the numerous florets produced **more** than 1,500 seeds during the **summer** of 1975 (Emery 1977). As with other **wildrice** species, freshly harvested seeds appeared to have an extended dormant period. When seeds were placed in spring water and refrigerated at **3 C**, 105 days were adequate to **break** the **dormancy**. Germination varied from 60-100 percent. The dormancy of Texas **wildrice** appeared related in part to the permeability of the **pericarp**. Germination (usually less than 50 percent) may be obtained soon after harvest by either puncturing or scraping the **pericarp** away from the embryo (Simpson 1966, Woods and Gutek 1974).

Seeds were germinated in petri dishes filled with well water which was changed daily. Seven to 10 days after germination the seedlings were transferred to pots containing river gravel. The pots were kept immersed a few centimeters below the water surface and care was taken to prevent currents that would disturb the seedlings. By the end of August 1976, about 500 sexual clones of Z. texana had been cultured.

Management Efforts: Clones of Z. texana were transplanted to other locations to ascertain if they would grow and produce viable seeds. An effort was made by Beaty (1972, 1975) to grow clones in **Salado** Creek in Bell County, Texas, because the habitat there was similar to that in the San **Marcos** River. The clones grew well and produced panicles. Unfortunately, local recreational activities plus periodic removal of aquatic vegetation from the springfed stream destroyed all clones planted. Since the area in **Salado** Creek was open to the public, it was impractical to isolate and to protect the transplanted Z. texana clones. On one occasion a bulldozer was used to clear the **creekbed** and banks, completely destroying the transplanted Texas wildrice. The effort to introduce this species in **Salado** Creek was abandoned after several years, since it was impossible to protect it from the general public. Most of the clones introduced into **Salado** Creek were from Emery's cultivated plants grown from seeds in a special raceway on the campus of Southwest Texas State University.

Emery transplanted more than 100 clones of nursery grown **wildrice** during the period 1976 to 1982 to various locations in central Texas, including the springfed Comal River, New Braunfels, Comal County, and a few other springfed sites in the vicinity of San Marcos. Transplanting efforts were unproductive and flooding washed away the plants before they established a firm rooting in the stream bed. **Transplantings** into Spring Lake were eaten by nutria, an introduced exotic rodent.

Emery's efforts to raise Texas **wildrice** seedlings were successful in the raceway. Currently, his efforts **have** been halted due to major construction underway at the university's Aquatic Station. Emery transplanted several of his nursery grown **wildrice** clones in a selected area in the upper reaches of the San Marcos River. In September 1982 these clones produced panicles and a few seeds. Due to the heavy recreational use of this particular portion of the river by swimmers, "tubers," and canoeists plus the floating debris from aquatic vegetation cut in Spring Lake, most of the **wildrice** fruiting heads were knocked over. Thus viable seeds could not be obtained at that time.

Research in a number of areas is needed in order to understand the factors influencing the survival of Texas wildrice. Such factors are poorly known.

Ecological factors such as natural grazers, competition and **compatability** with other native and introduced **taxa**, natural reproduction (sexual and asexual) cycles, and threats to **wildrice** habitat are critically needed. Portions of this research currently are being conducted for the U.S. Fish and Wildlife Service by Dr. Paul **Fonteyn** of Southwest Texas State University who has initiated an autecological study of the species.

In addition, information is needed on the growth and development of Texas **wildrice** in various habitats within its native range, cross fertilization and hybridization with other species, factors affecting seed germination and seedling development and growth, productivity, nutrient requirements, and potential economic value. The potential of reintroducing seedlings into natural habitats where Texas **wildrice** once was found, especially in Spring Lake and the upper San **Marcos** River environments, also should be investigated.

In his work with Z. **texana**, Emery was successful in seed collections, seed storage and germination, seedling survival, and development of survival clones to **the F<sub>2</sub>** generation through pollenization under controlled situations. Additionally, he successfully cross-bred Z. **texana** with **other** species of Zizania.

Since no recent seedlings **have** been observed in the native habitat in the San **Marcos** River, it is unknown if Z. **texana** can reseed itself with its present population size under existing environmental and anthropogenic pressures.

Actions for Immediate Preservation of the Species: The best **means** of preserving the species until **more** is known about its biology is by preserving the native habitat by minimizing human disturbance. Additionally, education of the public may help in this regard through talks, newspaper reports, and articles such as the one by Beaty (1975). Collection of federally listed plants is prohibited on Federal lands; **Z. texana** is found only on private lands and therefore receives no protection **from** collecting. Texas rules protecting native plants (957.402) allows collecting of listed plants with landowners permission. Both of these regulations need strengthening in order to protect **Z. texana**.

#### Threats to the San Marcos River Ecosystem

Because the San Marcos Springs' flow is tied inseparably to water usage over the entire Edwards Balcones Fault Zone Aquifer, human population growth coupled with increased utilization of groundwater in the region will decrease flow of water from the San Marcos Springs. Analyses by the Texas Department of Water Resources (TDWR 1977) projecting water usage from the aquifer through the year 2020 indicate that increased usage is expected well into the 21st century, especially in the San Antonio region. Because of the anticipated growth in this region of the Edwards Balcones Fault Zone Aquifer and the anticipated increased water usage, several estimates **have** been made concerning the influence of increased **pumping** on the spring flow at **San Marcos**. **Data** from the Bureau of Reclamation (**USDI 1972, 1973a, 1974**) **suggest** that demands on the Edwards Balcones Fault Zone Aquifer, even considering a "low" (and unlikely)

rate of growth for this region, will far exceed the recharge to the aquifer (Longley 1975). Given various schemes of water usage, the Bureau of Reclamation projects that the probability of **continuous** flow from the San Marcos Springs by the year 2020 is only **50-75** percent certain. According to Klemm et al. (1979) and assuming full projected development with average hydrologic conditions, the continued flow from the San Marcos Springs will cease around the year 2010. In other words, all projections predict that the flow from the San Marcos Springs will cease around the year 2000. This is the most serious threat to the continued existence of the San Marcos River ecosystem.

On a local scale, the City of San Marcos is growing rapidly (U.S. Bureau of the Census 1982). Edwards (1976) found that increased urbanization caused increased flooding and erosion (due to uncontrolled runoff), pollution, siltation, and a general decrease in species diversity and species numbers in adversely impacted aquatic environments. For **these** reasons, changes in the upper San **Marcos** watershed must be approached with extreme caution to avoid degrading any habitat suitable for these endangered and threatened species. A series of five flood retardation structures initiated by the Soil Conservation Service (U.S. Dept. of Agriculture 1978) on tributary creeks feeding into the San **Marcos** River is expected to decrease the severity of flooding in the watershed and to slightly increase the recharge into the aquifer. **This** is expected to have a slight overall benefit to this ecosystem.

Another threat to these species is ~~the~~ anticipated increase in storm water runoff as the city grows. This runoff should be discharged into the river at a point downstream from the essential habitat of these species.

Urban pollutants such as locally applied pesticides and herbicides also may be negatively impacting on the San Marcos species. The Texas Highway Department has ~~used~~ a herbicide (Roundup) along the bridge pilings and concrete aprons at the IH-35 crossing of the San Marcos River as a part of their highway grounds maintenance program for years (D. Chance, Texas Department of Highways and Pueblo Transportation, San Marcos, pers. ~~comm.~~) and a moderate to light rainfall could easily wash this compound into the river at the type locality of the San **Marcos** gambusia. Although the effects of this substance on ~~the~~ San Marcos species are not known, it may be more than coincidental that no G. georgei have been taken at this species' type locality since the spraying program was initiated. Other species could also be similarly affected.

Relatively constant water temperatures and flows apparently are required by these endangered and threatened species. Also, exotic species apparently pose a significant threat to the listed species because of similarities in habitats and diets. Some of the exotic species undoubtedly are predators on the species of concern.

Additional Threats to the San Marcos Endangered and Threatened Species

San Marcos Gambusia (Gambusia georgei)

In addition to spring flow, the San Marcos gambusia also requires relatively constant temperature regimes and shading in its habitats. Modifications arising from increased urbanization must **take** these factors into account. A secondary portion of the Soil Conservation Service plan is to upgrade recreational facilities-in the Rio Vista Park area. Since the entire range of G. georgei is immediately downstream from these facilities, extreme care must be taken during the construction phases to insure the protection of this species and its extremely limited habitat.

Exotic species pose a significant threat to G. georgei; this is especially true with Poecilia, which share many similarities in habitat use with G. georgei. Although Poecilia sp. in the San Marcos River exhibit broad thermal tolerances (especially to high temperatures), overlap in habitat **with G. georgei** appears especially great during winter and spring when thermally moderated, quiet, shallow habitats are chosen by all of these poeciliids. Juvenile **centrarchids and** cichlids in the San Marcos River also appear to share habitat similarities with G. georgei populations. In addition, the abundance of the **predaceous** characin (Astyanax mexicanus) may have an additional adverse impact on the abundance of San Marcos gambusia.

Competition for resources may be one factor which imposes extreme limits on the abundance of G. georgei. In addition to expected high levels of interspecific competition from other Gambusia, **especially** G. affinis, other less closely related species also have been found associated with G. georgei.

The following species are exotics in **the San Marcos** River but have been taken in G. georgei habitats: Astyanax mexicanus, Poecilia latipinna, P. formosa, Micropterus dolomieu, Lepomis microlophus, L. auritus, Ambloplites rupestris, Cichlasoma cyanoguttatum, Sarotherodon mossambicus and S. aureus. Abundances of Poecilia (both species), Lepomis (especially L. auritus) and the cichlids (all species) are high in the habitats where G. georgei are found. Interference from these species may inhibit the ability of G. georgei to recolonize the **San Marcos** River following perturbations such as flooding.

Studies **have** shown that many fishes (especially when small) have very similar food habits (Hubbs et al. 1978). If exotic, or nonnative, species are added to aquatic systems, greater competition or overlap among species is possible. These exotic species may be able to acquire resources with greater efficiency than native species. Also, during the exponential population growth phases of recently introduced exotics, even short term extensive niche overlap with G. georgei is likely to impact this species negatively.

Stability within the San Marcos River system apparently is **the** key to survival of that ecosystem. This stability will have the added benefit of not only insuring the protection of G. georgei, but conserving the other unique elements of the San Marcos aquatic environment as well.

Fountain Darter (Etheostoma fonticola)

It is possible that effluent from the sewage treatment plant has reduced the distribution of the fountain darter. In the early 1900s, the river was dammed (Cumming's Dam) in the area of Jordan and Gilbert's (1886) collection site, which changed **the** habitat and probably eliminated the species from this area. Water in this segment is fairly deep and muddy and the river banks are cut sharply. These conditions restrict the growth of many types of vegetation which E. fonticola prefers.

Nematodes were **the** most **commonly** encountered parasites of E. fonticola. The most common adult nematode was Camallanus sp. and the maximum number found in any one fish was six. Some fish contained many larval nematodes. Five darters each were parasitized by single strigeoid trematodes and two were hosts to single unidentified leeches (Schenck 1975).

San Marcos Salamander (Eurycea nana)

In addition to the general threats affecting this species, the San **Marcos** salamander is threatened with (1) an overabundance of predators **and** (2) **the** removal of vegetation which provides cover and harbors this

species' food supply (i.e., duck fecal droppings polluting moss habitat, ducks feeding on moss and algae, removal of algal mats by **Aquarena** Springs personnel).

Texas Wildrice (Zizania **texana**)

The location of Z. **texana** within the city limits of San **Marcos** makes protection difficult. Emery (1967) discussed the decline of the **wildrice** and mentioned some disturbing factors: (1) the regular mowing of aquatic vegetation in Spring Lake to make the lake more attractive to tourists allows floating masses of cut vegetation to move downriver and damage or break off the protruding inflorescences of wildrice, thus interfering with its pollination and reproduction by seed; (2) ~~the~~ periodic ploughing or harrowing of the river bottom by city workers to rid it of vegetation; (3) introduction of a lumber of exotic plant species and commercial harvesting of these and native aquatic plants for aquaria; and (4) raw sewage discharged into the river whenever the capacity of the city's sewage system is exceeded. Ten years later, Emery (1977) **reported** that the impact of these factors had abated significantly, but there still had been no reproduction from seed and no significant vegetative spread from existing clones. More recent field investigations by Emery and others indicate that the Zizania population has declined even more due to the above factors plus a 1980 flood which washed out many of the clones and further disturbed the habitat by physically changing the channel.

The **wildrice** appears particularly vulnerable to chemical changes in its aquatic environment. An additional threat is the ever present possibility of accidental pollution by runoff of locally applied herbicides, such as those applied to bridge overpass pilings by the Texas Department of Highways and Public Transportation, or of other contaminants.

Conservation Efforts

San Marcos Gambusia (Gambusia georgei)

Four individuals of G. georgei (2 males, 2 females) were raised in aquaria at the University of Texas at Austin following their capture on May 16, 1979. The individuals, along with their approximately 30 additional young, were transferred to the University of Texas Brackenridge Field Laboratory for outdoor culture during April 1980. Subsequently, individuals from this outdoor location were transported to Dexter National Fish Hatchery, Dexter, New Mexico, during August 1980 where they were maintained and propagated. In April 1982, those cultures were discovered to be contaminated by G. affinis and were subsequently eliminated. Studies have continued in an effort to document the presence of the San Marcos gambusia in the upper San Marcos River and to further knowledge of this rare species' abundance, habitats, and biological requirements. An effort **also** is being made to secure another sample **of** G. georgei for culture at Dexter National Fish Hatchery; however, the **extreme** rarity of G. georgei in the San Marcos River makes this an extraordinarily difficult task.

Fountain Darter (Etheostoma fonticola)

The major effort in understanding of E. fonticola was the thesis research of J. R. Schenck (1975), Aquatic Station, Southwest Texas State University, San Marcos, Texas.

The U.S. Fish and Wildlife Service maintained a stock of E. Fonticola at the Dexter National Fish Hatchery, Dexter, New Mexico, from 1974 until 1981. The stock, **supplied** by Clark Hubbs in 1974, consisted of 50 individuals from the San Marcos River. The fountain darters at Dexter were held to provide fish for reintroduction efforts should a catastrophic loss of the natural population occur.

Etheostoma fonticola has been successfully **reestablished** in the headwaters of the Comal River and the population at Dexter subsequently has been eliminated.

San Marcos Salamander (Eurycea **nana**)

Conservation efforts for **the** San Marcos salamander-primarily have involved determining basic aspects of its life history, abundance, habitats, and other factors affecting its survival (Tupa and Davis 1976). Efforts have been made to ensure the cooperation of the owners of **Aquarena** Springs Amusement Park in the management of this species in following management recommendations made by the Texas Parks and Wildlife Department biologists.

Texas Wildrice (Zizania texana)

Habitat conservation measures are in effect, accomplished through cooperation of the privately owned amusement park (Aquarena Springs) with management recommendations made by Texas Parks and wildlife biologists (Floyd Potter, pers. comm.). Efforts have involved reestablishing a population of Z. texana in Spring Lake and in the upper San Marcos River.

PART II

RECOVERY

Action Plan

Recovery objective:

The ultimate objective of the San Marcos Recovery Plan is to secure the continued survival of the four endangered or threatened species in their natural ecosystem and to describe the process by which the four species can be recovered to nonthreatened status.

**Stepdown** Outline

1.0 Maintain and enhance the San Marcos species in their present habitat.

1.1 Monitor existing populations and habitats.

1.11 Establish monitoring procedures and schedules.

1.12 Recommend **monitoring** personnel.

1.2 Identify individual and population needs and habitat requirements.

1.21 Determine competition levels with exotic (~~nonnative~~, -exogenous, ~~nonindigenous~~) species.

1.22 Determine food habits.

1.23 Identify diseases and parasites.

1.24 Determine reproductive parameters.

1.25 Determine survivorship patterns.

1.26 Determine effects of predation.

1.27 Identify habitat characteristics and requirements (including

flow requirements, temperature requirements, channel conformation requirements and other **niche parameters**).

- 1.28 Determine aquifer characteristics and **recharge** patterns and zones **which** influence flow from San **Marços** Springs.
- 1.29 Determine impacts from recreational use of the river upon the ecology of protected San **Marços species**.
- 1.210 Determine **characteristics** of the San **Marços** watershed.
- 1.211 Compile data pertaining to pesticide and herbicide use on the watershed.

1.3 Manage existing habitats and populations.

- 1.31 Establish guidelines with appropriate government agencies for the **management** of the San **Marços** River ecosystem.
- 1.32 Establish and maintain **captive stocks** at Dexter National Fish **Hatchery** and San **Marços** National Fish Hatchery.
- 1.33 Reduce pollution load of upper San **Marços** River habitats.
- 1.34 Augment recharge of aquifer to ensure continued flow.
- 1.35 Establish controls on groundwater pumping from aquifer.
- 1.36 Prepare water wells to ensure **continued** flow in river.
- 1.37 Restore damaged habitats and enhance marginal habitats.
- 1.38 Encourage management through private owners to ensure stability of the San **Marços** River Ecosystem.
- 1.39 Remove exotic (**=nonnative**) organisms from the San **Marços** River ecosystem.

1.4 Establish guidelines for recreational use of the San **Marços** River.

2.0 Conserve and protect habitat of listed species in the San **Marcos** River ecosystem by obtaining habitat management authority along the San Marcos River.

3.0 Law Enforcement

3.1 Inform necessary agencies of status and recovery efforts and confer with agencies with proposed projects which might affect the San Marcos species.

3.2 Enforce law pertaining to endangered and threatened species.

4.0 Public information and education.

4.1 Produce an information package (pamphlet, narrative slides, movie, etc.).

4.2 Encourage media releases.

4.3 Encourage public participation in conservation efforts.

5.0 **Recommend** changes in listed status as appropriate.

Action Plan Narrative

The objective of the San **Marcos** Recovery Plan is to secure the survival and eventual recovery of the four endangered or threatened species in their natural ecosystem. Protection of the San Marcos River ecosystem is vital to the survival and recovery of these four species. Once it is assured that the flow of the San Marcos River will continue with its natural cycle of variation and that other recovery measures described in this plan are accomplished, the species may be downlisted. This should occur through the implementation of this recovery plan. The recovery plan for the San Marcos River ecosystem is divided into two nonseparable sections each with overlapping objectives. For this reason, both "short term" threats to each of the species and "long term" threats to the ecosystem's continued integrity have been addressed. Only by addressing both types of threats and directing recovery activities toward remedying both can recovery of the listed species **occur**.

1.0 Maintain and enhance the 'San Marcos species in their present habitat.

Recovery of these four species will require efforts aimed at specific aspects of each species' biology in conjunction with efforts addressing the continued flow from the San Marcos Springs. The only natural populations of the Texas wildrice, fountain darter, and San **Marcos** gambusia inhabit the upper San Marcos River ecosystem. Fountain darters and San Marcos salamanders inhabit **the** Comal River in addition to the San Marcos River; however, the fountain darter population in the Comal River stems from a reintroduction of this species from stocks obtained at San Marcos after its extirpation from the **Comal** River.

1.1 Monitor existing populations and habitats.

In order to assess trends in population dynamics of the four listed species and to assess the effectiveness of recovery actions, each of the four species must be monitored and their populations **censused** on a regular basis. Because each species is unique with its own particular set of population parameters, the specific protocol involving each species must be unique to the particular population in question.

1.11 Establish monitoring procedures and schedules.

Initially, the populations of the **San** Marcos gambusia and the Texas **wildrice** should be monitored at least on a quarterly basis during the initial phases of any recovery action. The populations of fountain darters and San Marcos salamanders should be monitored at least twice each year, as their populations appear at present more stable than the other two San Marcos **River** protected species. As recovery actions are initiated and objectives require evaluation, these schedules will be modified. In monitoring each species, appropriate methods should be used to minimize interference. This is especially important with regard to the San Marcos gambusia as this species is critically in danger of extinction.

1.12 Recommend monitoring personnel.

Much of **the** current monitoring of the four San **Marcos** species has been done by members of the recovery team and by contractors with the U.S. Fish and Wildlife Service. As recovery measures are implemented, additional personnel likely will be involved in the monitoring of **the** species. The team recommends that qualified persons with appropriate training **be** utilized in carrying out these recovery objectives.

1.2 Identify individual and population needs and habitat requirements.

The biological parameters affecting and influencing the survival of the four San Marcos River protected species are not well understood although efforts toward a greater understanding of these parameters have been a major thrust of previous research. Only by conducting research on the San Marcos River species in their natural environments can success in assuring their survival in their natural ecosystem be accomplished.

1.21 Determine competition levels with exotic (=nonnative, =exogenous, =nonindigenous) species.

A relatively large number of potential competitors and predators have been introduced into the San Marcos River ecosystem by a variety of individuals and agencies. It is believed that these introduced taxa are affecting the listed San Marcos species; however, the level of this interaction is unknown. It is critically important to understand the effect these exotics are having on the protected species so that potential levels of competitive inhibition may be understood more fully. It is necessary to obtain life history information on exotics, especially those parameters such as overlap in habitat use, foods, critical life stages, and other interactions as may occur with the San Marcos species.

1.22 Determine food habits.

The food habits of the fountain darter and the San Marcos salamander have been examined; however, the foods taken by the San Marcos gambusia and the nutritional needs of the Texas wildrice have not been determined.

An examination of the food requirements of these species should be attempted with special emphasis on the selectivity of the species in obtaining various food resources and the distribution of preferred and highly desirable food items on a seasonal basis. The availability of preferred foods or nutrients also should be quantified seasonally, given the cyclic nature of the San Marcos River ecosystem.

1.23 Identify diseases and parasites.

Little information on diseases and parasites of the four listed species is available. The effects of these on population survival can be adverse. Diseases and parasites need to be studied in advance so that corrective management strategies might be implemented if a debilitating parasite infestation or an uncontrolled outbreak of disease occur.

1.24 Determine reproductive parameters.

A study of the reproductive cycles and patterns for the species should be accomplished to better understand the natural fecundities of the species and factors influencing the number of offspring each species can produce. From this information it may be possible to augment the natural reproductive rates of these species by providing optimum conditions for reproductive success, thus quickening the recovery of these species to their former levels of abundance.

1.25 Determine survivorship patterns.

The factors influencing the survivorship of each of the San Marcos protected species are inadequately known. Information concerning survivorship is critically needed as is information on optimal conditions for enhancing survivorship of these species. Studies should include analyses of such factors as predation and competition.

1.26 Determine effects of predation.

The role of predators on the survival of the San **Marços** species has not been studied in detail, although fountain darters have been found in stomach contents of largemouth bass (**Micropterus salmoides**) taken during winter months. Studies on predators in the San **Marços** River would provide data on the intensity of predation on the protected species, and knowledge of their rate of removal would contribute to concurrent analyses of survivorship potential of these populations.

1.27 Identify habitat characteristics and requirements  
(including flow requirements, temperature requirements,  
channel conformation requirements and other **niche** parameters).

Relatively few of the controlling niche parameters for any of the San **Marços** species are well known. Studies must be conducted to determine the various aspects of the environmental parameters **influencing** the survival of these **species** in order to best manage these populations and to ensure their survival by Considering all aspects of their biology.

1.28 Determine aquifer **characteristics** and recharge patterns  
and zones which influence flow from San **Marços** Springs.

Because the San **Marços** River ecosystem is tied intimately to the flow of the San **Marços** Springs and the springs to the Edwards **Balcones** Fault Zone Aquifer, information detailing the **hydrologic characteristics**

and trends of the aquifer is essential. Numerous agencies, including the U.S. Geological Survey, Edwards Underground Water District, Edwards Aquifer Research and Data Center, Texas **Department** of Water Resources, U.S. Army Corps of Engineers, Bureau of Reclamation, Soil Conservation Service, and various other organizations and groups, have conducted and are **continuing** to conduct investigations into the **functioning** of the aquifer. Additional information on the functioning of the aquifer in the San Marcos region and specifically studies which deal with those factors which can influence the flow from the San **Marcos** Springs are needed to evaluate **any** of the flow-related recovery actions.

1.29 Determine impacts from recreational use of the river upon the ecology of protected San Marcos species.

The usage of the San **Marcos** River by swimmers, "tubers," canoeists and others has increased dramatically in recent years. Their **combined** effect on the San **Marcos** River ecosystem is unknown; however, at least part of the reproductive difficulties of the Texas **wildrice stems** directly from human use of the river for recreational activities as emerging seed heads are knocked over or damaged by recreationists. Recreational use patterns should be documented, especially with regard to seasonal use patterns and trends, impacts on the protected San Marcos River ecosystem species and potential **means** to avoid **unintentional** adverse effects.

1.210 Determine characteristics of the San Marcos watershed.

Even though the San Marcos ecosystem is principally a springrun, run-off **from** the surrounding watershed strongly influences the water

quality and biota of the river. Consequently, knowledge of the characteristics of the watershed is necessary for its management. A description of the watershed **should** include the size, topography, slope, run off patterns, soil types and characteristics, land use patterns and acreages, **and** climatic characteristics.

1.211 Compile data pertaining to pesticide and herbicide use on the San **Marcos** watershed.

Pesticides and herbicides, if misused, could negatively impact the San Marcos ecosystem biota in degrees of severity ranging from subtle to catastrophic. Information should be compiled pertaining to pesticide or herbicide related fish or plant kills and agricultural and non-agricultural uses of herbicides and pesticides in the upper San Marcos watershed.

1.3 Manage existing habitats and populations.

Each of the San Marcos protected species' habitats and populations should be monitored and managed to maximize survival potential for each species. This is extremely important during early recovery efforts . because the populations, especially with respect to the San Marcos gambusia and Texas wildrice, are low at present and any activity which would further negatively impact these species numbers should be avoided.

1.31 Establish guidelines with appropriate government agencies  
for the management of the San Marcos **River** ecosystem.

In order to restore the San Marcos threatened and endangered species to a non-threatened status in their ecosystem, a unified set of guidelines for the management of the San Marcos River ecosystem should be established. Guidelines may need to be modified as each of the recovery objectives is fully implemented. Without the cooperation of all agencies involved with the flow of the San Marcos Springs or with the water quality parameters of the river, recovery of the San Marcos species is remote.

1.32 Establish and maintain captive stocks at Dexter National  
Fish Hatchery and San **Marcos** National Fish Hatchery.

Because of the limited range of each of the listed San **Marcos** species, a **catastrophy** could be disastrous for each of the species. stocks of San Marcos gambusia should be obtained and then cultured at the U.S. Fish and Wildlife Service facilities at Dexter, New Mexico and San Marcos, Texas. Because of limited culture success with any of the San **Marcos** species at the Dexter facility, additional stocks should be maintained closer to a source of San Marcos Springs' water. A cooperative agreement with **Southwest** Texas State University (SWTSU) may also be possible following negotiation **with** the appropriate **university** officials.

1.33 Reduce pollution load of upper San Marcos River habitats.

Water quality continues to be a problem in the upper San Marcos River as urbanization of the surrounding area increases. Catastrophic single events as well as chronic and persistent pollution incidents are increasingly likely to occur. These must be minimized to provide the San Marcos species the environmental conditions to which they are adapted and to properly evaluate recovery actions. New means of handling wastewater, street runoff, and other pollutant sources must be found for the City of San Marcos; stormwater runoff and occasional spills of sewage from both the wastewater treatment plant and from leaky collection systems currently are discharged into the San Marcos River. As the city has become increasingly urbanized, these problems have increased in frequency and severity.

1.34 Augment recharge of aquifer to ensure continued flow.

A possibility for enhancing the discharge of the San Marcos Springs is by increasing the recharge to the springs. Information regarding the location of suitable areas for recharge would be available with the completion of objective 1.28. If it is found to be ecologically compatible, recharge structures could be used to augment the flow of the San Marcos Springs in order to emulate natural flow regimes.

1.35 Establish controls on groundwater pumping from aquifer.

A possible means of maintaining natural flow regimes in the San Marcos River is by imposing controls on the pumping of groundwater. The achievement

of this objective will require the cooperation among the many entities involved on Federal, State, and local levels.

1.36 Prepare water wells to ensure continued flow in river.

Wells to maintain the natural flow variation regimes below Spring Lake can be a temporary means to achieve continual flow in the San Marcos River. Discharge from well pumps should be released at a point sufficiently downstream from the spring openings such to prevent recharge back into the aquifer through the spring openings. Pumping would protect against a catastrophic loss of the San Marcos species (except Eurycea nana, which is found only near spring openings) should a critical low or no-flow situation occur. It is recognized that this measure alone will not constitute a recovery action for ~~the listed species because~~ the prevention of a pump failure cannot be assured unequivocally.

1.37 Restore damaged habitats and enhance marginal habitats.

A goal to increase the numbers of each of the listed ~~taxa~~ could, be realized if damaged habitats were restored and marginal habitats manipulated for improvement of endangered species survivorship potential. The area surrounding the San Marcos City Park (downstream from the dam at Rio Vista Park) should be investigated as potential habitat for Texas wildrice. Restoration of the open substrate but shaded habitat of the San **Marcos** gambusia downstream from the IH-35 crossing of the San Marcos River also should be attempted.

1.38 Encourage management through private owners to ensure stability of the San **Marcos** River ecosystem.

Many private owners also can impact the San Marcos River ecosystem due to early water rights and other legal agreements. Every effort must be made to gain the cooperation of these users to ensure the integrity of the San **Marcos** River ecosystem. Efforts also should be made to gain the cooperation of recreational users of the San Marcos River since they have a large influence on the biota of the river.

1.39 Remove exotic (~~=nonnative~~) organisms from the San **Marcos** River **ecosystem**.

Exotic organisms, with ~~their~~ realized and potential effects on the San **Marcos** species, are not a natural influence on the San **Marcos** species or their ecosystem. For our discussions we define "exotics" as species which are not native to the San Marcos river area. A program of selective removal should be initiated to insure that only natural interactions occur among the inhabitants of the San **Marcos** River.

1.4 Establish guidelines for recreational use of the San Marcos River.

Guidelines for use of the San Marcos River by recreationists must be developed to protect the listed species and their habitat from unintentional misuse by the public. Methods to partially close sections of the San Marcos River to recreational use during critical or sensitive periods in the life history of species should be explored. Hopefully, public cooperation will aid in conservation of the San Marcos River species and the public will not be inordinately restricted in their use of the river.

2.0 Conserve and protect habitat of listed species in the San Marcos River ecosystem by obtaining habitat management authority along the San Marcos River.

Conservation of the San Marcos ecosystem is tied inseparably to conservation of the species' habitat in the river. By managing the river bank and access to the river, many impacts on the habitat can be reduced. Two entities which exert large influences on the San **Marcos** River ecosystem are the City of San Marcos and Southwest Texas State University.

3.0 Law enforcement.

Four San Marcos species (Texas wildrice, San **Marcos** gambusia, fountain darter and San Marcos salamander) are currently protected under U.S. and Texas laws. Efforts must be made to provide law enforcement agencies with current information concerning the identification and ecological requirements of each of the forms so that negative impact on **these** species from individuals or projects might be avoided.

3.1 Inform necessary agencies of status and recovery efforts and confer with agencies with proposed projects which might affect the San **Marcos** species.

Every effort needs to be made to provide current information about the recovery efforts, status, and needs of the San Marcos species and their ecosystem to agencies which could unintentionally negatively impact these species or interfere with ongoing recovery efforts. A systematic

procedure of consultation should be vigorously pursued for any activity involving the **Balcones** Fault Zone Aquifer and the San Marcos Springs and River so that negative effects from any project will be avoided.

### 3.2 Enforce laws pertaining to endangered and threatened species.

Adequate personnel must be provided such that recovery efforts are allowed a chance to succeed. Laws enacted to insure the integrity of these species should be enforced in such a manner as to maximize survival potential of the San Marcos species.

### 4.0 Public information and education.

It is imperative that the public become aware of and sensitive to the problems surrounding the survival of the San **Marcos** ecosystem and its unique flora and fauna. Means should **be** developed to inform the public and to gather public support for enhancing the status of the San Marcos endangered and threatened species. Materials produced for this objective should be directed toward **increasing the** public's general awareness of listed species and their plight, together with actions which would result in successful recovery.

#### 4.1 Produce an information package (pamphlets, narrative slides, movies, etc.).

A series of informational media packages should be prepared **detail-**

ing the factors influencing the survival of the San Marcos species and their ecosystem. The use of a multi-media approach such that all segments and age groups of the public, are aware of and informed on the problems facing the San Marcos River species. Formats can include informational brochures, slide packets (with and without supplementary narrative cassettes), movies and/or videotaped presentations.

#### 4.2 Encourage media releases.

As recovery objectives are completed and as the San **Marcos** species respond to recovery efforts, news releases should be distributed to appropriate media for informing the public. Also, if the status of any or all of the San Marcos species changes, these changes should be publicized through the media.

#### 4.3 Encourage public participation in conservation efforts.

In order for recovery of the San Marcos species to occur, the public must be involved in recovery activities. Human recreational activities are among those factors negatively impacting the San Marcos species. Every effort must be made to allow for public participation in recovery actions. Support programs for environmentally sensitive activities associated with the San **Marcos** River ecosystem need to be developed. These could be of the form of "San Marcos River Awareness" events specifically designed to enhance the public's awareness and empathy toward the plight of the San Marcos species and their ecosystem. A citizens' committee

also could be established to coordinate local efforts, provide input and direct citizen attempts in fostering awareness for the uniqueness of the San Marcos River ecosystem.

5.0 Recommend changes in listed status as appropriate.

As the recovery actions are implemented and there is reasonable assurance **that** the San Marcos River ecosystem will be maintained, much of the threat to the San Marcos species will **be** removed. Once this occurs, downlisting of the four species may be **accomplished** following careful review and evaluation of the recovery actions undertaken to that point. If the' natural dynamics of the San Marcos River **can** be assured and if following the evaluation of prior recovery actions it is determined that the species have responded positively to the recovery actions, then the four San Marcos species could be removed from the Federal list of Threatened and Endangered species. Upon removal from the Federal list, management authority for the species would reside with the State of Texas.

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PART III - IMPLEMENTATION SCHEDULE

Priorities in column four of the implementation schedule are assigned using the following guidelines:

- Priority one (1) - Those actions absolutely necessary to prevent extinction of those species.
- Priority two (2) - Those actions necessary to maintain the species' current population status.
- Priority **three** (3) - All other actions necessary to provide for full recovery of the species.

Abbreviations used: **TP&WD** - Texas Parks and Wildlife Department  
**TDWR** - Texas Department of Water Resources  
**EUWD** - Edwards Underground Water District  
**SWTSU** - Wouthwest Texas State University

GENERAL CATEGORIES FOR IMPLEMENTATION **SCHEDULES**

Information Gathering - I or R (research)

1. Population states
2. Habitat status
3. Habitat requirements
4. Management techniques
5. Taxonomic studies'
6. Demographic studies
7. Propagation
8. Migration
9. Predation
10. Competition
11. Msease
12. Environmental contaminant
13. Reintroduction
14. Other information

Acquisition - A

1. Lease
2. Easement
3. Management agreement
4. Exchange
5. Withdrawal
6. Fee title
7. Other

Management - M

- 1.** Propagation
2. Reintroduction
3. Habitat maintenance and manipulation
4. Predator and competitor control
5. Depredation control
6. Msease control
7. Other management

Other - O

1. Information and education
2. Law enforcement
3. Regulations
4. Administration

*needed actions*

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PART III - IMPLEMENTATION SCHEDULE

GENERAL CATEGORY	PLAN TASK	TASK #	PRIORITY #	TASK DURATION	RESPONSIBLE AGENCY		FISCAL YEAR COSTS			COMMENTS	
					FWS		OTHER	(EST.)			
					REGION	PROGRAM		FY 1	FY 2		FY 3
(1)	(2)	((3))	(4)	(5)	(6)		(7)	(8)			(9)
M3	Establish monitoring	1.11	1 <sup>2</sup>	ongoing	2	Mgmt.	TP&WD	10,000	7,500	7,500	
M3	Recommend monitoring	1.12	2	ongoing	2	Mgmt.	Rec.	1,000	1,000	1,000*	Part of req. team ann. rev.
110	Determine competition levels with exotics	1.21	2	5	2	Mgmt.	TP&WD	10,000	10,000	10,000*	
I3	/Determine food habits	1.22	2	3	2	Mgmt.	TP&WD	10,000	10,000	10,000*	Should be done along with Task #1.21
111	Identify diseases and I parasites	1.23	2	3	2	Mgmt.	TP&WD	5,000	5,000	5,000	Should be done I along with Task #1.21 & 1.22
I6	Determine reproductive I parameters	1.24	2	3	2	Mgmt.	TP&WD	10,000	10,000	10,000*	Should be done with 1.21,1.22
16	Determine survivorship patterns	1.25	2	3	2	Mgmt.	TP&WD	5,000	5,000	5,000*	Should be done with Tasks # 1.21, 1.22, 1.23 & 1.24

\*Costs refer to USFWS expenditures only.

PART III - IMPLEMENTATION SCHEDULE

GENERAL	PLAN TASK	TASK #	PRIORITY #	TASK DURATION	RESPONSIBLE AGENCY			FISCAL YEAR COSTS			COMMENTS
					TP&WS		OTHER	(est.)			
					REGION	PROGRAM		FY1	FY2	FY3	
(1)	(2)	(3)	(4)	(5)	(6)		(7)	(8)			(9)
19	Determine effects of predation	1.26	2	3	2	Mgmt.	TP&WD	10,000	10 ,000	10 ,000	Should be done with Tasks # ~1.21, 1.22, 1.23, 1,24, & 1.25
13	Identify habitat requirements	1.27	2	3	2	lgmt.	TP&WD	10 ,000	10 ,000	10 ,000	Should be done with Tasks # 1.21, 1.22, 1.23, 1.24, 1.25 & 1.26
12	Determine aquifer characteristics and recharge patterns	1.28	2	3	2	lgmt.	DWR Edwards	25,000	15,000	25,000*	
I4	Determine impacts of recreational use of the San Marcos River	1.29	2	5	2	lgmt.	City of San Marcos	5,000	5,000	5,000	
112	Determine characteristics of the San Marcos watershed	1.210	3	2	2	Mgmt.	scs TP&WD EPA		5,000	5,000	
I12	Compile data pertaining to pesticide and herbicide use in the watershed	1.211	3	2	2	Mgmt.	scs TP&WD EPA		5,000	5,000	Should be done with 1.210
M3	Establish management guidelines	1.31	2	2	2	lgmt.	DWR City of San Marcos		10,000	10 ,000	

PART III - IMPLEMENTATION SCHEDULE

GENERAL	PLAN TASK	TASK	PRIORITY	TASK DURATION	RESPONSIBLE AGENCY			FISCAL YEAR COSTS (est.)			COMMENTS
					FWS	OTHER		FY1	FY2	FY3	
(1)	(2)	(3)	(4)	(5)	REGION	PROGRAM	(7)	(8)			(9)
M1	Maintain captive stocks	1.32	1	ongoing	2	Mgmt.		8,000	8,000	8,000*	
M3	Reduce pollution of San Marcos River	1.33	2	ongoing	2	Mgmt.	EPA TDWR City of San Marcos	115,000	15,000	15,000*	Should be done with 1.31
M3	Augment recharge to aquifer	1.34	2	ongoing	2	Mgmt.	TDWR Edwards Under-ground water I District	115,000	15,000	15,000*	Should be done with 1.28
M3	Establish controls on groundwater pumping	1.35	2	ongoing	2	Mgmt.	TDWR EUWO	125,000	25,000	25,000*	Should be done with 1.31
M3	Prepare wells to insure continued flow in river	1.36	2	3	2	Mgmt.	EUWD Aquarena Springs Inc.	120,000	20,000	20,000*	Should be done with 1.31 & 1.35
M7	Restore and enhance habitats	1.37	2	ongoing	2	Mgmt.	TDWR City of San Marcos	150,000	50,000	50,000	Should be done with 1.29, 1.31 & 1.36
M7	Encourage management	1.38	2	ongoing	2	Mgmt.	EUWD TOWR	5,000	5,000	5,000*	Should be done with 1.29, 1.31, & 1.37

PART III - IMPLEMENTATION SCHEDULE

GENERAL  (1)	PLAN TASK  (2)	TASK # (3)	PRIORITY # (4)	TASK DURATION (5)	RESPONSIBLE AGENCY			FISCAL YEAR COSTS (est.)			COMMENTS  (9)
					FWS	OTHER		FY1 (8)	FY2	FY3	
					REGION (6)	PROGRAM	(7)				
M4	Remove exotics	1.39	2	3	2	lgmt.	TP&WD TDWR city of San Marcos	100,000	100,000	100,000*	Should be done with # 131, 1.37, & 1.38
M3	Establish quidelines for recreational use of the San Marcos River	1.40	2	ongoing	2	lgmt.	city of San Marcos SWTSU	5,000	5,000	5,000*	
A3	Conserve and protect habitat	2.0	2	ongoing	2	lgmt.	City a San Marcos	75,000	75,000	75,000*	Should be done with 1.27, 1.29, 1.31, 1.38,
03	Inform state and Federal agency	3.1	2	ongoing	2	lgmt.	TP&WD TDWR EUWD	5,000	5,000	5,000*	
03	Enforce laws	3.2	2	ongoing	2	lgmt.	TP&WD TDWR City a San Marcos	20,000	20,000	20,000*	
01	Information package	4.1	2	ongoing	2	lgmt.	EUWD SWTSU	5,000	5,000	5,000*	

PART III - IMPLEMENTATION SCHEDULE

GENERAL  (1)	PLAN TASK  (2)	TASK #  (3)	PRIORITY #  (4)	TASK DURATION  (5)	RESPONSIBLE AGENCY			FISCAL YEAR COSTS (est.)			COMMENTS  (9)
					FWS		OTHER	FY1 (8)	FY2	FY3	
					REGION (6)	PROGRAM	(7)				
01	Encourage media releases	4.2	2	ongoing	2	Mgmt	EUWD City of San Marcos	5,000	5,000	5,000*	
01	Encourage public participation	4.3	2	ongoing	2	Mgmt	EUWD City of San Marcos SWTSU	5,000	5,000	5,000*	
1	Recommend changes in listed status	5.0	3	2	2	Mgmt			3,000	3,000*	

APPENDIX

COMMENTS AND RESPONSES

The following **comments** were received from reviewers of the technical and agency review draft of the San Marcos Recovery Plan and are listed alphanumerically, e.g., A1, A2, etc. Responses to comments are **also** listed alphanumerically in the same sequence as comments.

A1 - Done

A2 - Done

A3 - Done in part.

A4 - No plan exists or is anticipated for translocating any of the San Marcos listed species to habitats outside of areas described in this recovery plan, i.e., the San Marcos and **Comal** Rivers.

A5 - Done

A6 - Done

A7 - The entire plan discusses the topic. The San Marcos River is the habitat for these four species and its continuation **as** a natural habitat will dictate the survival of its endemic species.

**A8** - The plan discusses genetic swamping to the fullest extent permitted by available information.

A9 - Species accounts were made as consistent as possible given the amount of information available on each species. Updates will be made when additional information becomes available.

**A10-** Done

A11- See A7 above. Recommendations for management of the Edwards Plateau and Aquifer are beyond the scope of this recovery plan.

**A12-** Done

**A13-** Please refer to sections entitled "Stepdown Outline" and "Action Plan Narrative."

- A14- While emphasis has been placed on the rarest of the listed species in the San Marcos River (wild rice and gambusia), it should be noted that this is a habitat recovery plan rather than a species recovery plan. If the stream is protected, the species will survive.
- A15- The recovery plan is intended as a first stage of managing the organisms, habitats, and factors influencing the ecosystem towards the goal of recovering the Federally listed components of the ecosystem. Feasibility of implementation is in the eye of the beholder and unless we know what should be done to recover the species, we will never achieve it.
- A16- Done
- A17- Noted
- A18- The recovery plan acknowledges the use of Edwards Aquifer water in excess of recharge and makes general suggestions regarding regional use of aquifer water. However, this recovery plan is intended as a biological document; a thorough discussion of groundwater use would be inappropriate and would not enhance or emphasize the importance or urgency of the recovery actions described in the recovery plan. Long-term survival of the San Marcos River, while noted in the plan, is left for others to address.
- A19- The Texas blind salamander (Typhlomolge rathbuni) is a federally listed threatened species. Service listing activities related to other Edwards Aquifer troglobitic **taxa** are underway. Consequently, the subterranean portion of the Edwards Aquifer ecosystem, which is broader than the San Marcos system, will be addressed **more** appropriately in later documents. If San Marcos Spring should fail, its endemic species will **be** lost, but those species inhabiting the aquifer will survive until the aquifer is polluted or runs dry, a much longer term problem. Also refer to Task 1.28.
- A20- The plan conforms to Service policy regarding recovery plan content and format.

- A21 - The objective of the plan is to secure the survival of 4 species in their natural ecosystem. This will be accomplished by providing habitat that will allow populations to attain carrying **capacties**. Historic populations are unknown and are therefore unattainable.
- A22 - The San Marcos **gambusia** has changed its distribution but not its habitat preference. Distribution of the species' habitat has changed because changes have occurred in the San **Marcos** ecosystem and the fish are following suitable habitat. Also the scarcity of the species strongly infers that little preferred habitat remains anywhere in the species historic or present range.
- A23- Reports of fountain darters from other than the San Marcos or Comal Rivers can not substantiated. It seems most likely the species is endemic to the aforementioned rivers using biogeographic techniques.
- A24 - Any unpublished literature lacks peer review. It is recommended that the referenced materials be read for content.
- A25 - The plan does not suggest "that population growth over the entire Edwards Aquifer is the most serious threat to the recovery of the four species." Cessation of flow from the San Marcos Springs is the most serious threat to the San Marcos ecosystem.' Nor does the plan address population control.
- A26 - The plan fully addresses the historic range of the species. Service policy does not allow introductions **outside** historic range. Reintroduction of endangered species outside of their historic range is not an option for recovery. **By** definition, historic range involves those localities in which the species is known to have existed.
- A27 - The referenced **economic** analysis **was** neither written nor reviewed by the recovery team and is not part of the recovery plan. The recovery plan &scribes the best **approach(es)** to assuring the continued survival of the four listed species.
- A28 - To suggest that aquatic organisms are becoming extinct because they are unable to adapt to dry land **shows** an unusual lack of understanding for both evolution and the reasons the San Marcos and Comal Rivers are going dry. The purpose of the Endangered Species Act is to recognize these problems and prevent the extinctions.
- A29 - The plan attempts to provide for the survival of four threatened or endangered species and the continuation of their critical habitat. Section 7 of the Endangered Species Act (consultation) **is one** method of achieving this objective.

A30 - Done.

A31 - Delisting of the species is feasible. The objective was reworded.

**A32** - Delisting is feasible. The **Stepdown** Outline and Task 1.37 were changed.

A33 - Assigning quantifiable goals may be possible when tasks related to determining the population status and habitat requirements are accomplished.

**A34** - Agreed.

A35 - Done.

A36 - Done.

THE UNIVERSITY OF MICHIGAN  
ANN ARBOR, MICHIGAN, U.S.A. 48109

MUSEUM OF ZOOLOGY  
DIVISION OF FISHES

✓	JOHNSON	✓
✓	Bowman	✓
	Curley	
	Halvorson	
	Hoffman	
	Kologiski	
	Langowski	
	KAYSER	
	Hoop	
	Padilla	
	SANCHEZ	
FILE <i>SMART</i>		

July 1, 1983

Dr. James E. Johnson  
Endangered Species Biologist  
U.S. Fish and Wildlife-Service  
P.O. Box 1306  
Albuquerque, New Mexico 87103

Dear Jim:

Enclosed is the Draft of the San Marcos Recovery Plan with my comments in red. A few, made late at night, may not be appropriate, but I believe most of them are worth consideration. Many of my comments are editorial.

A-1 One thing recovery plans have been doing recently is to give  
A-2 the author of the scientific name when the name is first  
mentioned (p. 2). This is standard procedure in many scientific  
journals. Also, it is customary to give month, day and year for  
status determination of taxa in the Federal Register (p. 7).

I would like to say that this is the most comprehensive and well-written Recovery Plan I have seen and the Team is to be congratulated.

Cordially,

*Bob*

Robert R. Miller  
Curator of Fishes

RRM:cgz

Encl.

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JUL 5 '83

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-98-

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY  
WASHINGTON, D.C. 20460

✓	Boyer	✓
	Carney	
	Hoffman	
	Kelley	
	Langoski	
	KAYSER	
	Hughes	
	Pedilla	
	SANCHEZ	
FILE <i>SMART</i>		

8 JUL 1983

DRD	_____
AA	_____
✓ AFF	<i>P</i>
AWR	_____
AHR	_____
LE	_____
PAO	_____
EEO	_____
X FILE	<i>SE</i>
OFFICE OF CLERICAL SERVICES	

Department of the Interior  
U.S. Fish and Wildlife Service  
Washington, D.C. 20240

Attention: Larry Thomas  
Office of Endangered Species

Dear Mr. Thomas:

As requested, we have reviewed the draft Recovery Plan for the San Marcos River Endang./Threat. Spp. which this Branch received on 6/9/83. We appreciate the opportunity to comment on the merits of this document and trust that the enclosed comments will be useful in completing the final Recovery Plan.

*Raymond W. Matheny*

Raymond W. Matheny  
Supervisory Biologist  
Ecological Effects Branch  
Hazard Evaluation Division

3.

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AUG 19 1983

OFFICE OF THE  
REGIONAL DIRECTOR

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8 JUL 1983

I have reviewed the June 9, 1983 draft of the San Marcos Recovery Plan for the following endangered and threatened species:

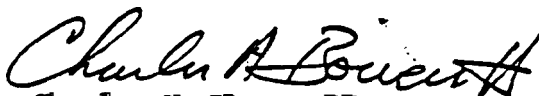
1. San Marcus Gambusia (Gambusia georgei)
2. Fountain Darter (Etheostoma fonticola)
3. San Marcus Salamander (Eurycea nana)
4. Texas Wildrice (Zizania texana)

- 3 The proposed recovery plan recognizes the potential threat of pesticides to Texas wild rice but makes no mention of the remaining three species. The Ecological Effects Branch (EEB) is charged with the responsibility of assessing the impact of both new and currently registered pesticides on federally protected species. Therefore, we respectfully request that you modify your objective 1.2 to include parameters that would aid our Branch in identifying potential "may effect" situations. Examples of the type of information needed to conduct a site specific hazard assessment are cited below:

1. The nature of the drainage basin involved, including but not limited to size, topography, slope, and runoff characteristics of the surrounding watershed.
2. Description of the surrounding soil types, pH, % organic matter, moisture content, etc.
3. Acreage and land use patterns (e.g., cropland, rangeland, etc.) in the surrounding San Marcos Watershed.
4. Climatic factors including annual average temperature and precipitation.
5. Information pertaining to any previous pesticide related fish kills.
6. Information concerning non-agricultural uses of pesticides (e.g., rights-of-way, mosquito control, power plants, pesticide manufacturing or formulating plants, etc).

t-4 -- Objective 1.31 indicates plans to develop a translocation effort. As all of our protection efforts are limited to known locations for federally protected species, we suggest that translocation plans include a mechanism for providing EEB with written notice as to the date and location of these releases. Such information is consider&vital if EEB is expected to protect new populations from possible adverse exposure to pesticides.

EEB welcomes the opportunity to further communicate with the recovery team staff through OES concerning the exchange of information which could be mutually helpful in assessing the effects of pesticides on federally protected species.



Charles A. Bowen, II  
Fisheries Biologist  
Ecological Effects Branch  
Hazard Evaluation Division (TS-769)



# United States Department of the Interior

FISH AND WILDLIFE SERVICE  
WASHINGTON, D.C. 20240

ADDRESS ONLY THE DIRECTOR.  
FISH AND WILDLIFE SERVICE

In Reply Refer To:  
FWS /OES

JUL 22 1983

End. Sp. R-2	RD
JOHNSON	DRD
Bowman	AA
Carley	AFF
Halvarson	AWR
Hoffman	AHR
Kologiski	LE
Langowski	PAO
KAYSER	EEO
Hopp	FILE
Padilla	CLERK
SANCHEZ	SE
FILE	SMRT

## MEMORANDUM

To: Regional Director, Region 2 (ARD/AFF)  
Deputy Associate  
From: Director

Subject: Review of the San Marcos Recovery Plan - Technical Draft

We have completed review of the subject plan. The Region should be commended on producing a very thorough and comprehensive document. However, the format is inconsistent with the prescribed format as defined in the Recovery Guidelines. Please review the Guidelines and revise accordingly. A generalized format is attached for additional guidance. Specific comments will be found in the margins of the attached copy of the text. More general comments are given below.

- A-5 1. Though the recovery team was instrumental in developing this plan, references (noted in the margins of the text) to the team's opinions should be deleted.
- A-B 2. A more detailed map (Figure 4) of the San Marcos area should be included, especially noting the relationship of the Springs to the overall area. Also, if there is any connection between the Springs at Comal and those at San Marcos, the map should indicate this, as well. A similar map indicating historic distribution should be included, if pertinent.
- A-7 3. There is no discussion in the text describing the availability or extent of suitable and potential habitat. If habitat is lacking, there should be a discussion describing the management actions necessary to restore the habitat.
- A-8 4. The discussion on hybridization (page 12) fails to discuss the importance of mate competition relative to reproductive success. If both G. georgei and G. affinis are competing for a limited number of mates (G. georgei), the abundance of G. affinis may preclude the former species from successful reproduction. The plan should state whether this and other forms of competition from exotics are a problem.
- A-9 5. The species accounts are not consistent in content. Such topics as habitat requirements, associated species, protection and research needs are not fully discussed for all species.
- A-10 6. It is not clear in the discussion whether or not the Comal Springs and River are being considered under this plan. If there are viable populations of E. fonticola and E. nana in the Comal area, their protection and recovery should also be discussed.

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- 11 7. The major problem facing these species seems to result from a reduction in flow and the effects this would have on the habitat. The importance of maintaining or increasing flows and its relationship to habitat maintenance is not discussed. Since this is directly related to Tasks 1.33, 1.34, and 1.35, this should be fully discussed and any problems documented.

r- 12 8. The section on threats (page 45) is poorly written and should be expanded. This should include a more thorough discussion of the past, present, and future threats to these species, including a discussion on how past actions have led to the present situation. This section should also mention expected changes to the habitat, describing the impact on the species and its habitat. This discussion will form the basis for our recovery actions.

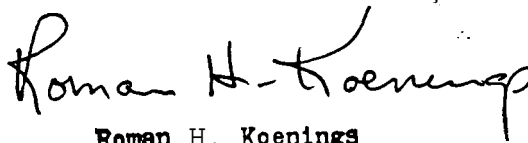
- 13 9. The text of the document should conclude with a thorough discussion of the projected management actions that may be taken to protect and manage the species and habitat. This section should include quantifiable and measurable criteria for downlisting and delisting, if possible. This section will then logically lead into the step-down outline.

- 14 10. As written, the step-down outline is too general and vague to be useful. The discussion in the text leaves the impression that the San **Marcos gambusia** and possibly the Texas wild rice (this is unclear) are on the verge of **extinction**. If this is the case, the outline should focus its objectives on the protection of these two species. Recovery efforts on the darter and salamander can be delayed and our resources more wisely used on the gambusia and wild rice. Efforts expended for the protection and recovery of these two species would also have a positive effect on the salamander and fountain darter.

- 15 Secondly, the outline should provide a specific step-by-step plan of action for the management of this area. From the discussion, it appears as though recovery is not feasible. Therefore, the plan needs to provide a feasible set of objectives and actions. For example, from the description of expected development, it hardly seems realistic to expect Tasks 1.33, 1.34, and 1.35 to be implemented. If not, what steps can we take? This conflict between **management** and recovery should be resolved and the outline rewritten accordingly. If it is the intent to produce a separate **management** plan this should be identified. If the recovery plan is to fill that role, it needs to be more specific.

- 16 The outline should also be ranked within and between subgroupings. For instance, Task 1.3 seems to be the most important. It should be stated first. When completed, the outline should present specific proposals whose objectives and actions are logical and well defined.

We hope these **comments** will be helpful in preparing the agency draft. If you feel that the above comments do not warrant revision of this draft, please explain in your return cover memo. Please submit five copies of the agency draft for our review.

  
Roman H. Koenings

THE UNIVERSITY OF MICHIGAN  
ANN ARBOR, MICHIGAN. U.S.A. 48100

MUSEUM OF ZOOLOGY  
DIVISION OF FISHES

End. Sp. R-2C
JOHNSON
Bowman
Carley
Halverson
Hoffman
Kolodiski
Lanowski
KATSER
Hoan
Padilla
SANCHEZ
FILE <i>SMRT</i>

July 22, 1983

Dr. James E. Johnson  
Endangered Species Biologist  
U.S. Fish and Wildlife Service  
P.O. Box 1306  
Albuquerque, New Mexico 87103

Dear Jim:

This is a follow-up to my 1 July letter commenting on the Draft of the San Marcos Recovery Plan.

A- 17 If I recall correctly no reference was made in the accounts of Texas Wild Rice or the San Marcos Salamander to the IUCN accounts of these two species. The former appeared in Red Data Book Vol. 5 on Plants, the latter in Red Data Book Vol. 3 on **Amphibia** and Reptilia. Copies of these two accounts are enclosed and the same go to Clark.

The IUCN (International Union for Conservation of Nature and Natural Resources) regarded Texas Wild Rice as "Vulnerable" (=our Threatened category) and the salamander as Rare.

Best wishes,

*Bob*

Robert R. Miller  
Curator of Fishes

RRM:cgz

Enc. (2)

cc: Clark Hubbs

cc: Bob Edwards/8-10-83/vah

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SANTA BARBARA • SANTA CRUZ

Department of Biological Sciences  
(805) 961-3511

Santa Barbara, California 93106

✓	Johnson	90
X	Bowman	
	Carley	
	Hartman	
	Hoffman	
	KANISER	
	Hops	
	Padi na	
	SANCHEZ	
FILE		SMRT

August 4, 1983

Mr. J.E. Johnson  
Acting Assistant Regional Director  
U.S. Fish and Wildlife Service  
P.O. Box 1306  
Albuquerque, New Mexico 87103

Dear Mr Johnson:

Enclosed please find the review draft of the San Marcos Recovery Plan. I have made **comments** throughout the text.

I have had considerable field experience with salamanders of the genera Eurycea and Typhlomolge in central Texas, and am well acquainted with the geology and hydrology of the Edwards Plateau. My familiarity with Etheostoma fonticola, Gambusia georgei and Zizania texana is slight; thus, I have restricted my **comments** to points concerning Eurycea nana and the hydrology of the Balcones Aquifer.

I have three strong overall impressions of the enclosed draft Recovery Plan. First, I believe the findings and **recommendations** it advances are biologically sound and carefully considered, and that the ecosystem approach it advocates will be effective in the short-term.  
A-18 Second, I am not at all convinced that the long-term preservation of the system and species of concern is adequately addressed in this Recovery Plan. The real problem facing the aquifer is excessive groundwater use on a regional scale (particularly in the vicinity of San Antonio); the local measures proposed do recognize the problem, but are not effective solutions. All projections indicate that the aquifer will be reduced to a critical degree within 25-50 years, and no amount of local relief efforts will prevent major alteration of San Marcos and Comal Springs.

Third, since this plan advocates an ecosystem approach, I am puzzled that little attention is given to the subterranean component of the aquifer. The problems are common to surface and subterranean environments, since today's river flow was yesterday's ground-water. The incredible rich troglobitic fauna of the San Marcos aquifer is at least as deserving of conservation efforts as is the surface-dwelling component.  
A-19 I feel the Recovery Plan should take larger notice of the subterranean portion of the system, and use this to help strengthen the **case** for an effective, regional response to the ground-water use crisis which threatens to destroy the biological uniqueness of the entire aquifer.

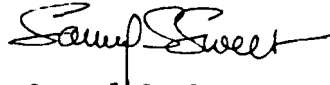
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Mr. J. E. Johnson  
August 4, 1983  
Page 2

I have included some information (collection data and field notes) on Eurycea nan at Coma7 Springs to augment the material presented in the draft Recovery Plan.

Sincerely,

A handwritten signature in cursive script, appearing to read "Samuel S. Sweet".

Samuel S. Sweet  
Assistant Professor of  
Biological Sciences

SSS:ad  
Encl.

MEMORANDUM

To: Lisa Hemmer, Esq.  
Wildlife and Marine Resources Division  
United States Department of Justice

From: Matthews & Branscornb, attorneys for  
Edwards Underground Water District

Date: September 9, 1983

Subject: Edwards Underground Water District v. Watt, et  
al., W.D. Texas No. SA-80-CA-410

Comments of the Edwards Underground Water  
District on the Technical Review Draft of the San  
Marcos Recovery Plan and the Economic Analysis or  
Recovery Scenarios.

Thomas P. Fox, General Manager, and Russell Masters,  
Assistant to the General Manager, of the Edwards Underground  
Water District prepared written comments on the Technical Review  
Draft of the San **Marcos** Recovery Plan and the Economic Analysis  
of Recovery Scenarios provided to us by the Defendants in the  
referenced suit in accordance with the stipulation.

The District officers **also** solicited comments from  
interested officers and staff of certain other public entities  
engaged in water management or other activities related to the  
Edwards Aquifer. Written comments were received from three of  
these, the Texas Department of Water Resources, the **Nueces** River  
Authority, and the San Antonio River Authority. Summaries of  
certain of the comments of the outside respondents have been  
incorporated in this Memorandum, which the District presents as  
its official comments. For your information, **copies** of the  
comments received from the outside respondents **are** attached.

---

Part I. THE TECHNICAL REVIEW DRAFT

The Technical Review Draft of the San **Marcos** Recovery Plan  
(the "Draft Plan") is not fully responsive to the Stipulation nor  
to the need to preserve the four species for the following  
reasons:

1. Most of **the** Plan provides technical and historical data  
**rather than a plan for action.** The technical data should be  
attached as an appendix.

A-2 1 2. One objective of the recovery plan is to restore the historic population of the species. The Draft Plan should describe the historic population of the species.

3. The current and historic distribution of the species is an important component in understanding the problems facing the species. Therefore the following matters should be clarified or explained:

A-22 (a) The report states that G. gorgei appears to have significantly altered its distribution over time. This means that in less than 100 years it has completely changed its habitat preference.

A-23 (b) References to the apparent presence of the fountain darter in any location other than the fault springs are dismissed as misidentification or some other mistake of the observer. no explanation is provided about how the conclusion is reached.

A-24 (c) It is suggested that Bogart's study of the life histories of the Texas Eurycea, in which he reported locating E. nana at several places other than San Marcos Springs, is deemed unreliable because it is unpublished. Yet a subsequent reference to Sweet's study regarding historic distribution, also **unpublished**, is included without comment.

A-25 4. The Draft Plan on page 43 suggests that population growth over the entire Edwards Aquifer is the most serious threat to the recovery of the four species. Although the Plan does not address population control directly, it is obvious that the recommendation of control of groundwater pumping from the Aquifer (Action Plan 51.34) is an indirect method of population control.

A-26 5. Reintroduction of the species is not sufficiently addressed in the Draft Plan. The District contends that there must be a serious effort to examine the possibility of relocation of the four species to localities in which the species could have occurred naturally. There is no proof that the locations suggested by the District for relocation are not part of the historic range. The possibility of a broader historic range has been ignored in the Draft Plan.

A-27 6. Section 1.3 provides only four direct action recommendations of real significance: (1) establishment of captive stocks of the endangered species; (2) augmentation of recharge of the Aquifer; (3) control of groundwater pumping from the Aquifer; and (4) use of pumps to maintain flow in the San Marcos River. The Economic Analysis, however, states that neither the recharge of the Aquifer nor pumping into the San Marcos River would insure

species survival. It also concludes that control of pumping would be complicated and the results inadequate.

A-28 7. In general, the Draft Plan sets forth elaborate, extensive, costly and restrictive proposals to fulfill the objective of protecting four endangered species, which appear to have become endangered not so much because of man's actions, but because they have been unable to evolve to the point that they can adapt to their environment. This phenomenon is not unusual in nature.

A-29 8. The Draft Plan appears to be an attempt to provide a case for indirect federal control on pumping from the Edwards Aquifer by requiring the proposer of any federal activity in the area to initiate the consultation process.

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# United States. Department of the Interior

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WASHINGTON, D.C. 20240

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In Reply Refer To:  
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Memorandum

To: Regional Director, Region 2 (ARD/AFF)

From: Acting Associate  
Director

Subject: San Marcos Recovery Plan - Agency Draft

As we stated in our July 22, 1983 (see attached memorandum), review of the technical draft, the recovery team has produced a well written and thorough document. This plan could serve as an example for others preparing recovery plans. However, some of the concerns we raised in our previous comments are still pertinent. Though the court case involving the San Marcos species has been resolved, the importance of this plan is not diminished. For example, as stated in the introduction, this plan represents our first attempt at an ecosystem approach. Also, from all indications, the survival of at least the gambusia is in question. Therefore, it seems imperative that the plan address the immediate protection of this species to assure its survival. Though we will not reiterate most of our previous comments, this latter statement plus others will be addressed below.

The present threats and conservation efforts affecting these species are well documented in the plan. However, the discussion in Part I leaves the impression that the survival of these species may be in question. Therefore, it is suggested that you consider the following comments: JUN 18 1984

- A-30 1. Include a discussion in Part II that ties together the threats to the species and habitat, the needs of the species (for example, on page 30 for the salamander), and the capability of the habitat to meet those needs.
- A-31 2. The Introduction (Part I) and Recovery Objective (Part II) specify the primary objective as delisting; however, this doesn't seem feasible considering the species status and the present and future threats. The primary objective should be rephrased to make this clear, if this is true. Task 1.13 should be omitted or renumbered as Task 5.
- A-32 3. If delisting is not feasible, the Stepdown Outline should be modified to stress management and protection. The need for intensive and coordinated management is indicated by the discussion. This should be clarified and Task 1.37 given more importance.

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4. If possible, the goals should be quantified for each species with estimated timeframes included.

A-33

5. The outline should be prioritized to present an orderly progression of recovery tasks. This will facilitate improved decisionmaking regarding allocating funds for recovery actions.

A-34

6. The Implementation Schedule should be rewritten to reflect any changes made from the above **comments**. However, regardless of the changes made, the **subtasks** from the **Stepdown** Outline (i.e., Tasks 1.11, 1.22, 1.37, etc.) should also be included in the **Implementation Schedule** with or in lieu of the primary tasks (i.e., Tasks 1.0, 1.1, etc.) and given appropriate priorities.

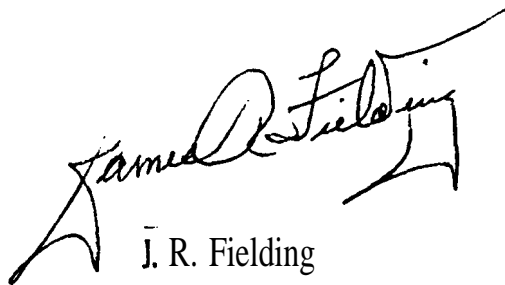
A-35

A-36

7. Also, Part II should begin on a new page.

We appreciate the effort the recovery team **has** put forth in developing this plan. If you disagree with our **comments**, please respond in writing. Please return five copies of the final plan for, the Director's approval and signature.

Attachments



J. R. Fielding